CORE BUSINESS: SEIZING OPPORTUNITIES IN RISK MANAGEMENT
A Generic Fuzzy Logic Prediction and Monte Carlo Simulation Method

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heijmans

Abstract

Implementing innovations and extending the core business increases both project opportunities and threats. Securing profit margins requires construction companies to redevelop their risk management process to prevent threats and promote opportunities. This research provides a renewed risk management methodology based on theory and practice. The traditional definitions terms involved with risk management are redefined and a framework is proposed using the definitions as restraints. In turn the activities in the framework are used as outline to create a supportive tool composed of the risk analysis and risk management principles. The main activities encompass identification, assessment and development of control and response measures. The assessment is supported by a combined fuzzy logic prediction system and Monte Carlo simulation tool to provide each risk with impact characteristics in terms of money and time. The renewed method provides a verified and validated approach to increase internal implementation and external application of risk management.

Keywords: Risk analysis, Risk management, Fuzzy logic, Monte Carlo simulation

Note: Summaries in both English and Dutch are included at the end of this research

Preface

Lying in front of you is the result of my master thesis as closure of my graduation internship at Heijmans Non-residential (Utiliteit). The research is the conclusion of the master program Construction Management & Engineering at the Eindhoven University of Technology (TU/e).

It was my aim to create a research which held both academic and social value. Extending this aim with my personal desire to accelerate the ongoing integration in the construction market and a challenging research subject certainly ensued. The internship at Heijmans gave me the opportunity to realise a research that actually contained all of these aspects, encompassed in the subject risk management. Creating a new method demanded the application of all knowledge I assimilated during my studies regarding process and project management and with complex construction projects at its basis all desires were fulfilled. Due to this fulfilment and all activities deployed during the process, I look back contented on the process and the final result. The research and my time at Heijmans in particular, allowed my to develop on a personal, academic and professional plain.

Completing the thesis however hasn't been the endeavour of a single person, hence I would like to use this opportunity (how striking) to thank those involved. First of all I would like to thank Bauke de Vries and Jan Dijkstra for their academic guidance and constructive feedback throughout the research. Especially your knowledge regarding the different methodologies and your safeguarding of the overall process, ensuring I did not lose sight of the deadline, proved helpful.

Secondly I would like to express my gratitude towards Coen Titulaer, my supervisor at Heijmans. Your involvement in the subject and continuous enthusiasm meant a great support throughout the research. I truly thank you for the trust, support and effort you expressed during and beyond my internship.

Finally I would like to thank all others that supported me throughout the research. My family for supporting me, not only during the thesis but also my entire studies, my collegues with their intellectual and expert remarks and my friends for kindly reminding me that Fridays are not meant for studying or research, however inconvenient.

Ruud van Beek
Eindhoven, March 2013

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List of abbreviations

BAFO	Best and final offer
COA	Centre of area
DBFMO	Design, build, finance, maintenance and operate
DMU	Decision making unit
FL	Fuzzy logic
HI	Heijmans Infrastructuur
HIGP	Heijmans Infrastructuur Geïntegreerde Projecten (Dutch)
HM	Her Majesties
HPPP	Heijmans Private-Public projects
MCS	Monte Carlo simulation
OT	Opportunities & threats
PMP	Project management plan
RA	Risk analysis
RAP	Risk analysis process
RISMAN	Risk management (method-name)
RM	Risk management
RMF	Risk management framework
RMM	Risk management method
RMO	Risk management overview
RMP	Risk management process
RMS	Risk management statement
RP	Risk profile
SE	Systems Engineering
SLC	Success likelihood category
TFN	Triangular fuzzy number

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1 Introduction

Risk is everywhere, whether it is a project, process or overall development. Although risk is commonly seen as threat, it equally provides plentiful opportunities to differentiate the organization relative to the competitors, ergo creating a competitive advantage. Being capable of identifying and managing those risks is the criterion when creating this advantage, expressing itself in e.g. better cost control, solution driven design practices and the ability to implement innovations. To keep the latter going, future developments should take into account these changes and the factors that urge these changes upon the market. Recently lots of attention has been developed towards innovative forms of collaboration. Integrated collaboration between different disciplines is deployed in an increasing manner by both clients and contractors.

Building projects are experiencing a paradigm shift from traditional tenders towards integrated contracts in which different phases of a project are outsourced to a single private party in a combined manner. By doing so the contracting party takes all responsibility regarding the alignment of the different project phases, with as target the optimization of the life cycle. Design, build, finance, maintenance and operate (DBFMO) are possible phases that can be taken up into an integrated contract. These phases can be combined, based on the desired amount of influence the client wishes to express on the process during both the realization and completion of the project. Besides the in-between alignment of phases, the different disciplines will be brought together early on in the process, operating conjointly during its entire length. Integration of knowledge while thus take place during the early stages, allowing for the development of solutions regarding technical issues resulting in possible gains on both the financial and qualitative plane (Rijksgebouwendienst, 2008).

The benefits add to the successful realisation of the project. This success is based on the realised price-quality ratio of the erected building and the supplied facility service during its operational phase. In their turn, these are compared to the desired end results as stated by the client. Projects no longer enter the market based on a detailed building plan, but the client defines a functional demand specification. It is up to the market parties to turn this demand specification in to a viable solution. Doing so allows the contracting party the space and flexibility to realise the earlier mentioned benefits during the development and exploitation of the project. Innovative solutions are increasingly being developed and deployed to answer to the clients desires for quality and sustainability. The lack of knowledge concerning the application of these innovations and the subsequent results adds to the necessity of the business and cultural shift. Storing and processing knowledge concerning these innovations during the project could add to the applicability. This is however partially countered due to the characteristic nature of building projects. Often being unique, location bound productions, building projects are commonly realised by ad hoc project teams with high turnover rates. Thus possibilities to coordinated storage and application of knowledge gathered during previous or running projects are limited. This points out the uncertainty inherent to construction projects, creating projects risks.

In this introduction, the focus will be to identify both the need for and the aim of engaging in risk management. After creating an insight in the research environment and motivation, the research objectives are defined through a problem statement, research question and sub-questions. Due to limited resources in the form of time, limitations are set to create objective focus during the research. With the motivation, objectives and limitations in place, the research outlines and structure are provided to explain how this research was conducted.

1.1 Market context

According to Zook and Allen (2001) is '*the foundation of sustained, profitable growth a clear definition of a company's core business*', a statement which is gaining foothold in the construction market amongst others. Clients are increasingly desiring a facility that will guaranty the ability to focus solely on their core business activities (Fleuren, 2012; Titulaer, 2012), resulting in a paradigm shift for construction projects. New ways are being sought to raise the level of environmental and economical performance whilst simultaneously raising the quality of the facility. Achieving these goals means extending the definition of the construction market to include conception, construction, operations, retrofitting and maintenance of the build environment (ECTP, 2005). Rather than reducing the activities, the construction market needs to extend its core business. According to Fleuren (2012) actual construction will become an activity of minor importance in the future. Where-as normally risks are regarded as an inherent aspect of the market, thinking in and seizing of opportunities is still perceived as a distinguishing feature (ING Economisch Bureau, 2012). Extending the activities leads to new opportunities alongside the project's risks. Adding the former to the profile description leads to the combined '*risk profile'* (RP), a list of all project risks and opportunities. The newly added opportunities indicate through which activities new margins can be obtained. These margins are small thus need securing via proper risk control measures. Whilst extending the profile, the influence on the profile has increased as well. With the heightened influence, contracting parties have the possibility to unroll better risk management methods.

1.1.1 RP control and management

Managing the RP includes modelling the project's objective functions against project variables. Due to the stochastic and dynamic nature of variables, the objective functions express uncertainty in either a positive (opportunity) or negative (risk) sense (Jaafari, 2001). Following the market shifts, three elements that categorize these objective functions and variables can be identified within the RP:

First, integrated contracts are deployed to convey which activities are to befall to the contractor's responsibilities. Listing these activities results in a project outline indicating in which phases the contractor can express his influence on the RP. Simultaneously it encompasses the legal aspects regarding the dividing of responsibilities between client and contractor.

Second, all disciplines needed to realize the acquired activities are gathered via integrated project approaches and structures, such as DBFMO. Obtaining the responsibility of several, subsequent project phases allows the integration of different disciplines at the point of tendering in order of obtaining both project and life cycle optimization. The manner of collaboration between the different disciplines is expressed as internal departments or external parties, together with the adoption of a subsequent mindset, forms the social aspect that influences the RP.

Third, the client increasingly expresses his desires regarding quality via EMVI[1]. These desires don't influence the RP as such since they form the source of the opportunities and risks that reside within the project. Clearly identifying both desires and the following opportunities and risks results in clear objective functions. In turn, clear descriptions of the selected management methods are conveyed to the client to elaborate the level of control, covering the commercial aspects of managing the RP.

1.2 Business context

This master thesis research is performed during a research internship at Heijmans N.V.. This construction company, with a total revenue of 2,4 billion euro in 2011 and 8.100 employees, is the third largest construction company in the Netherlands. Heijmans N.V. is listed at Euronext and the head office is located in Rosmalen (Heijmans, 2012a).

Heijmans set the ambition to become '*the leading building company in terms of profitability, quality and sustainability by 2015*'. Heijmans developed a strategy to achieve this ambition, in which disciplines and expertise are bundled from draft design to ongoing maintenance. Within this strategy a selective contracting policy is pursued focusing on growth of margin. Following this strategy, Heijmans distinguishes itself through its integral project approach. According to Bert van der Els, CEO, (Heijmans, 2012b) is Heijmans' integrated approach the answer for the current difficult market. Opportunities in integrated projects are seized, contributing to the projects results. Operational processes need improvement to maintain the momentum of this advancement. Such improvements include cost reduction, process improvement and selecting projects based on margin rather than volume.

Both the strategy and the integrated approach are leading for the division 'Heijmans Utiliteit' - the Non-residential Building division (intended in the remainder of the report if referred to as 'Heijmans'). This division is the result of a merger between the 'Non-residential Building division' (Heijmans Utiliteitsbouw B.V.) and 'Technical Services' (Burgers Ergon bv installatietechniek). This merger improves the possibility to develop and realize integrated contracts by combining the disciplines construction and installations in one division, which leads to synergy benefits and ultimately to buildings increasingly meeting customer needs over a longer period of time. Together with this merger, the management of the department were renewed and improvements were made regarding the project's acquisition and preparation phases. The projects selection focuses on the markets healthcare, government, commercial property, high-tech clean rooms and data-centres. The integration resulted in an increase of projects in the first half year in 2012 alone, compared to 2011 (Heijmans, 2012b; Mertens, 2012)

Comparing the market shifts and the focus of Heijmans' strategy, a distinct resemblance is noted, hence Heijmans provides a suitable platform and subject to conduct research regarding the management of opportunities and risks. To limited the scope, the research is conducted within newly merged division.

[1] 1. EMVI stands for '*Economisch Meest Voordelige Inschrijving*' (Dutch – Economical Most Profitable Tender-offer), a tender procedure for structuring and qualifying the client's quality desires via value add-on or price reduction.

1.3 Research framework

Although extension of the core business results in possible new margins, those actually achieved in today's difficult market are limited and leave little room for failure in order of maintaining a profitable position. Simultaneously the quality of the execution still needs raising via additional improvements. These improvements are realized through the merger and include cooperation, front end efficiency and knowledge development, risk management (RM) in the execution phase, reducing failure costs and meeting the demand for service and maintenance for existing clients and new projects (Heijmans, 2012a).

Alongside the overall project and process improvements deployed within the division, a specific focus has been placed on RM. In order of improving the development and execution of projects, new initiatives have been introduced together with a further refinement of the organizational direction. In addition to these developments, the demand for identifying and initiating follow-up steps to improve RM arose. This was in turn accompanied by the efforts of ensuring the proper functioning of the internal RM and control systems (Heijmans, 2012a).

1.4 Problem Statement

The above mentioned indicates that within Heijmans awareness and efforts regarding RM are growing. However, as markets are shifting, an adequate response is needed to both upkeep profitable margins and to maintain a leading market position. The latter is endorsed by the focus on integrated projects within a niche market. Simultaneously, clients express the tendency of increasingly shifting liability towards Heijmans in general, with financial liability and liability regarding design in particular (Heijmans, 2012a). To maintain an even or pro-active pace with these developments, Heijmans is in need of adequate RM method (RMM), therefore the following problem statement is formulated:

> *[PS]* Changes in the construction market result in new activities and subsequent responsibilities that befall Heijmans. Hence, the company needs to know how the risks originating from this <u>core business extension</u> can and should be managed to <u>secure profit margins</u>.

1.4.1 Research questions

Based on the problem statement the research question is devised as following:

> *[RQ]* 'How should Heijmans either improve or redevelop their RMM to achieve the desired increase in <u>internal implementation</u> and <u>external, commercial application</u>?'

To develop a better insight on the subject, the research question has been split into several sub-questions each covering a single sub-topic. By uniting the answers of the sub-questions a conclusion can be formulated answering the research question. These sub-questions create a stepwise funnel process, increasing the level of detail per step and additionally functioning as a roadmap for the overall research For this research the sub-questions are formulated as following:

[SQ.1] ‘What are the reasons of the dysfunctional state of the current method?’

[SQ.2] ‘Which methods are currently available for structuring the RM process (RMP) and which one/ones are most suitable for future use in the construction market?’

[SQ.3] ‘How can the gathered information of the structured RMP be documented to provide clearly defined arguments or metrics to support the decision making process?’

[SQ.4] ‘How can the newly or redeveloped method support the implementation of RM by achieving the desired mindset amongst personnel?’

[SQ.5] ‘How can Heijmans achieve the most suitable bid in terms of price and quality for the client, based on the defined risk characteristics and developed measures?’

1.5 Research objectives

As can be deduced from the sub-questions, the objectives of this research can be divided into two parts. First, the main objective is to either improve the existing or redevelop the RMM. This method consists of the theoretical background, a structuring process framework and a functional tool. Internally, this method will provide clear descriptions of opportunities, risks and the developed control and response measures, simultaneously indicating whom is responsible for each a measure. The method is targeting the complete project-line, running from the phase at which the project is put in the market for tendering, through completion of the object and until the maintenance and exploitation. Externally, the method’s tool will provide clearly defined opportunity and risk statements that will adhere to the client’s desired RM statement. To validate this aspect, a case study is conducted using an existing case.

Second, to steer the usage of the method, a guideline is needed. This guideline indicates how the method and the underlying model are to be used, adopting the model needs guidance. Describing the correct manner of applying the method will improve its adoption rate and the efficiency once implemented.

1.6 Limitations

The research itself is conducted within a limited time span. Therefore limitations are created for the scope of the research. In total three limitations are regarded, funnelling with each increase in detail. The uppermost limit is formed by the division in which the research is conducted. Due to the primary focus on Non-residential building projects, the method might need alterations when applied by other divisions. Although a organisation wide implementation could be regarded as the desired final state, creating a wide application would require extensive and extended, cross-division research.

The second, mid-level limitation focuses on the project phases. At the point of tendering, the risk and opportunity descriptions are abstract and gain more level of detail once the phases progress. By limiting the initial application and implementation to the tender-phase means the level can remain abstract. This is needed to obtain an overall method that encompasses all aspects without losing its value due to too much, detailed (product specific) information. The idea is to obtain an overview of all opportunities and risks that might surface during the following project phases at an early stage, so possible control and response measures can be designed.

Validating the model will be done by running a case with the focus on energy management. The target here is to test and prove its functioning. The subject of energy management is selected to demonstrated the usefulness of seizing responsible opportunities and risks when developing a fitting, sustainable and durable solution for design demands and all players included in the project. Verification is performed using an existing, integrated project to judge whether the redeveloped method provides an improvement in comparison to the original, currently applied method.

1.7 Methodological justification

In order of answering SQ.1 and SQ.2 a literature study is performed. Literature regarding previously performed RM research is gathered. From this literature the deployed methods, their application and results are structured and compared to describe suitable risk categorization and methods to structure these categories. This information is extended by gathering empirical knowledge through applied and current RM documents, documentation of completed projects and interviews with experts.

With the needed information gathered and structured, an answer can be provided for SQ.3 and SQ.4. The article by Alaneme and Igboanugo (2012) proposing a method based on 'fuzzy logic' (FL) and 'Monte Carlo simulation' (MCS) lies at the base of the developing a method that foresees both in the documentation and creating the desired mindset. The performance of many opportunities and risks are influenced by imprecise and uncertain factors, making measurement of such events subjective and uncertain. By introducing FL the impact magnitude of either the opportunity or risk impact can be predicted. Through this approach the uncertain nature of opportunities and risks are considered, based on expert experience and managerial subjective judgement (Nasirzadeh et al., 2008). Developing the most suitable bid is then done by simulating and comparing scenarios using MCS with the predicted magnitude as input. MCS is introduced to simulate the occurrence rate of each opportunity and risk in the project. As a result of the simulations a total required risk budget can be obtained which can be compared in size relative to the total project cost to determine how much risk is imbued in the project. The project opportunities and risks are summarized in terms of money and time, simplifying the usage and improving the communication both internally and externally. Obtaining the needed information and input for both model aspects is to be achieved via expert interviews and questionnaires.

Answering SQ.5 is combined effort of the results from SQ.1 to 4. A bid most suitable for the client without simultaneously jeopardizing the organizational functioning, relies on a full assessment of the projects opportunity and risk elements to determine where the strong point and points of attention reside within each project. Creating the management of the elements around these points directs the efforts towards the most suitable and profitable bid. Communication of opportunities and risks should be limited to those of interest to the client combined with the required risk budget as part of the margin. Selective communication allows Heijmans to convey their client-oriented RM statement (RMS) approach and outcome to the client.

1.8 Research relevance

Since this research is conducted from the viewpoints of both the TU/e and Heijmans, the contents should hold relevance for both entities. By identifying relevance is identified for both, it can be merged into a single holistic target for the research simultaneously foreseeing in the integration between theory and practice.

1.8.1 Relevance TU/e

Two aspects of the research can be identified supporting the TU/e based academic relevance. First, most of the research regarding risk management is descriptive-driven, lacking the generation of pragmatic and prescriptive results (Staveren, 2009). By adopting the method as proposed by Alaneme and Igboanugo (2012) and Nasirzadeh et al. (2008) and altering it to fit the current developments in practice generates an academic approach with practical applicability. Simultaneously, the method will encourage and urge the market to adopt integrated contracts providing flexibility, sustainability and durability for current and future projects by seeking out opportunities and accepting risks responsibly.

Second, according to Staveren (2009) all focus in risk management is on '*the development and application of new risk management methodologies, rather than the routinized application or implementation of existing risk management methodologies in organizations'*. Scientifically there is close to no information regarding implementation. This research tries to bridge the gap between existing methods, their applications and practical implication. Developing a method that conveys the needed information for all parties involved means not only a numeric, theoretical tool, but also a practical, social instrument improving communications during every project phase.

1.8.2 Relevance Heijmans

For Heijmans this research will serve the demand for a professionalization of RMM. By identifying the opportunities and risks that occur with the implementation of integrated contracts at the point of acquisition, clarifies the RM throughout the project duration. Through a uniform approach, all concerning departments and disciplines are ensured of a single manner in which risks are analysed and managed, resulting in a more efficient approach. Simultaneously, the renewed information can be added to the tender-offer, increasing the quality of this very offer by replying to the growing demand amongst clients for a clear RMS. Heijmans will gather the ability to take responsible substantiated risks with predetermined resources, cutting back losses during realization.

1.9 Expected Results

Following the research objectives, the expected result is a new or renewed RMM. This method consists of a documentation and assessment of possible opportunities and risks occurring during the project duration, followed by a model that is capable of turning the opportunities and risks into quantified data and possible measures. The information regarding the alternatives is to be presented via a '*dashboard*' to simplify the conveyance of information. Such a dashboard will also simplify the adoption of the method because of limited effort needed by its user. This adoption is supported by the second outcome as well, a process structure explaining the application and implementation of the method. Such a structure will support the understanding of the new model, improve the efficiency and reduce the possibility of erroneous implementation.

1.10 Research outline

With the market situation, business context and motivation of the research in place, the outline for the research progression will look as following: The second chapter concerns the analysis of the current situation and RMM to determine what the causes are of the current dysfunctional state. The analysis will encompass analysis of the current method and its outcomes, comparison with comparable method as used within the entire organization and user feedback. Following this analysis is properly defining the concepts involved with RM in chapter 3. Since these concepts lie at the basis of the entire method, a misconception a concept will result in skewed development of the process approach. Chapter four will take these definitions and apply them as the rigorous outlines for the development of a renewed RM framework (RMF). Such a framework will form the basic path every time the RMP is deployed in a project. Based on this framework, a supportive tool is developed in the 5th chapter. Besides supporting the RMP, a tool should be perceived as an instrument for the user to engage in RM and as a managerial tool for the tender or project manager. Providing a clear system for storing and conveying information is the core task of such a tool, coupling it to the framework creates a holistic RMM approach. The difficulties with quantifying and defining probabilities are covered by implementing FL and MCS. In chapter 6 the actions required to collect the opportunity and risk data are explained first, together with appointing responsibility regarding these actions and RM as a whole. This is followed by validation and verification. The validation is used to explain how the gathered data is stored by using the developed tool, together with judging the tools functioning. The following verification is judging whether the tool delivers as assumed by running an existing case and comparing the original outcome with the renewed results. Based on the performance, it can be decided to disperse the tool within the organization. The final chapter, chapter 7, will encompass the conclusions and recommendations that stem from the results gathered during the development of the framework, the tool and the validation and verification that is performed. Simultaneously the chapter directions for future research are proposed.

2 Problem analysis

As stated in the research proposal the *[RQ]* is '*How should Heijmans either improve or redevelop their RMM to achieve the desired increase in internal implementation and external, commercial application*?' This question indicates that the current method doesn't function as desired. Effectively foreseeing in the aim of either improving or redeveloping first requires the identification and analysis of the problems that led to this non- or dysfunctional state. To do so, the current method will assessed by studying its components through interviews with the users, workgroup discussions and a *within case study* of the method's functioning. As desired result of the assessment an overview of all influencing factors is crafted. Each of these factors will form the basis for the following in-depth research aiming at improvement or redevelopment.

2.1 Current method

Identification of the elements which led to the non-functional state first requires a understanding of the current method and subsequent tool. In this paragraph the origins, targets, structure and tools of the method are discussed.

2.1.1 Method origins

RM is described as '*the total of coordinated activities to direct and control a project organization with regard to risk'* (Van well-Stam et al, 2003). Within Heijmans[2], RM initiated from the increasing demand to create SMART (specific, measurable, attainable, realistic and timely) design and construction processes. Conducting RM requires a method capable of structuring the subsequent activities. Based on the experiences in integrated projects, the RISMAN method as deployed by Heijmans Infra (HI) was used as baseline. The RISMAN method (which is an abbreviation for risk management, taking the first three letters of each word) originates from the market's desire for a structured method capable of analysing and controlling project risks. The method was devised in the period 1995-1996 by a divers team consisting of '*Gemeentewerken Rotterdam, Prorail, RWS Bouwdienst, RWS Directie Zuid-holland, TU Delft and Twynstra Gudde'*. Over time, the method was improved through empirical information resulting in an enhanced theoretical basis and increased practical applicability. In 1998 the move was made to urge the market from merely analysing risks towards managing risks with the support of guidelines and brochures (Werkgroep RISMAN2, 1998). From this baseline a new method was created specifically designed for the application in non-residential building projects. Overtime, using the experiences gathering during usage, the method kept on developing whilst adhering to the SMART-targets. (Frits Dirckx, Appendix B.1)

2.1.2 Method targets

RM requires a basic outline to describe the features of the concept. In normal day society '*risk*' is regarded as a happening with an unfavourable outcome. The Oxford dictionary (2012) explains risk as '*exposure of someone or something valuable to danger, harm or loss'*. This description indicates both an event and the subsequent outcome (impact) of that event. A more extensive description in the dictionary explains risk as '*incurring the chance (or possibility) of unfortunate consequences by engaging in an action'*, thus adding the concept of possibility or chance. Adding the subject of project management results in the following,

[2] Non Residential is abbreviated to 'Heijmans' since it forms the division in subject for this research; if Heijmans as organisation is intended, the affix N.V. is added, the same goes for division other than Non-residential.

commonly applied, risk definition: '*Engaging in activities bringing about the possibility of adverse influences on the project's objective, resulting in increasing cost, project planning overrun or even the inability to complete the project.*'

In order of effectively structuring the RM Heijmans' method was created with specific targets in mind. The main target and essence of the method is identifying risk prone situations or objects with an increasing level of detail, supported by a proactive user stance. This identification consists of cause and the subsequent risk recognition, followed by the development of suitable response and remediation measurements. The results of this main target creates a chain reaction for the functioning of several specific targets, such as improved communications, effective cost management and environmental management.

During project development multiple disciplines are involved in the process, leading to a large number of different products. The large diversity in both disciplines and products creates an extended knowledge base and documents to support the identification, thus supporting the main target. However, individual identifications demands a structured documentation to embed the knowledge in the process. Once documented, the findings can be used for both internal and external communications in order of opening a dialogue with the project team and clients. In such a dialogue, the findings can be discussed between key players targeting the development of suitable response and remediation measurements. Simultaneously it prevents individual measures and actions, improving traceability of decisions and safeguarding the overall project and process performance.

In many cases, RM is performed to reduce disturbances and their negative effects on the overall project costs. Such reduction is based on early investments in remediation measures, reducing or nullifying the risks and the costs of manifestation. Frits Dirckx (Appendix B.1) states that '*small investments made early in the process, lead to positive, financial benefits during realization*'. Obtaining the necessary financial resources requires the client's willingness to invest. This willingness is created by conveying the retrieved information regarding the identified risks and befitting measurements, indicating the importance of communications.

Next to the client, it is equally important to notify the environment of the project activities or even to have them participate. Early awareness leads to acceptance in case of a possible disturbances. Here creating the willingness results in costs rather than investments, the eventual result however is targeting the reduction and remediation as well. Involvement through notification creates a positive mindset and acceptance amongst the users in the direct environment of the project. The total set of activities deployed to realize this target is called environmental management.

2.1.3 Method structure

To achieve these targets, the method is divided and structured into activities. These activities guide the RMP in a stepwise approach and indicate which supportive tools are available. As mentioned before, the RISMAN method as deployed at HI served as baseline. Both the activities and the structure in which they reside are based on this RISMAN method, resulting in the model as depicted in Figure 2.1.

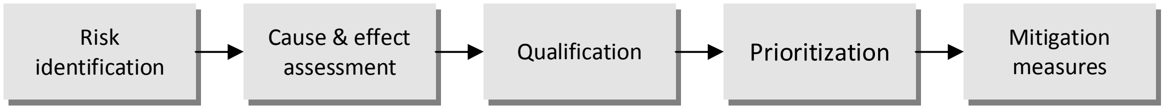

Figure 2.1: Structure and activities in the current RM method

- **Identification** is the first activity in the structure and points out the tasks of finding and describing the risks that might influence the project or the process;
- **Cause & effect assessment** is an extension of the identification to find the factors that influence and get influenced by these risks;
- **Qualification** encompasses the activities adding value or range to the fully identified risks and subsequent factors. This activity is done based expert and user knowledge. Structuring this activity the is done by making of the control aspects know as GOTIKV (Dutch - Geld, Omgeving, Tijd, Informatie, Kwaliteit, Veiligheid). Manifestation of risks influences one or more of these control aspects and thus requiring identification;
- **Prioritization** is placing emphasis on the control of the most influential risks. This influence is deduced based on the number of control aspects influenced by the risk, multiplying the impact with the risk probability or a combination of the two.
- **Mitigation measures** are developed to remediate or respond to the risks. Simple actions can be bound to these measures together with ownership, giving direction and ensuring active management. The most influential risks are given the most attention when finding suitable measures.

Once the measures have been defined, they too receive a value for the expected costs off implementing the measure together with the subsequent activities and the residual risk. These costs are defined for each risk and when combined, they form the *risk budget*. This budget is then downgraded for '*unknown unknown*' risks, unforeseen risks with an unknown probability and impact, eventually resulting in the totally required resources needed to negate risks. Reducing these costs is a possibility but requires an active stance of the employer in the thought process.

2.1.4 Method tools

Supporting this structured process is the RM overview, or RMO. This RMO is a table in which the output of each activity can be documented. Since all the outputs are structured in the same order as the activities, the RMO simultaneously serves as supportive tool for the RM process. The documentation is structured into *categorization, risk and/or opportunity description, qualification, mitigation measurements* and *residual risk*, resembling the structure of the RMP. One additional notion is adding the categorization to the identification, defining the element as risk or chance and whether it is manageable or beyond control.

Besides supporting the entire RMP, the RMO also helps guiding the identification by proposing four fields of focus: *order backlog, contractual conditions, building product* and *leading opportunities/risks*. These fields serve as reference guides giving direction to the though process involved with identification. It also urges users to think about risks and opportunities outside of their knowledge scope.

Since RM isn't an expertise carried by every user, a supplementary guide is provided describing the main target of RM, different abbreviations, the functioning of the tool and how changes are to be managed. Both tools are provided alongside each other, but the guide is a separate word file. The position of these tools are shown in Figure 2.2.

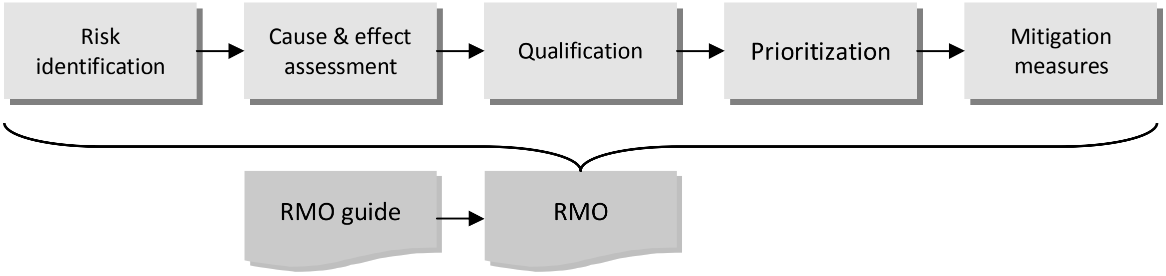

Figure 2.2: The position of the tools/documents in the current RM method structure

2.2 Method case study

Judging the functioning of the method, including the structure and tools, requires an analysis of empirical data. This analysis is performed using a single embedded case study (Yin, 2009). Due to the multiple levels of analysis this method is selected as the most suitable to obtain an in-depth insight in the performance of the method when implemented in project development within Heijmans. A single embedded case study is characterised by an analysis of one or more units of analysis embedded in a single case within its context. Since the analysis is conducted solely within Heijmans, it adheres to the characteristic of being a single case. The study is not conducted organization wide, but with the focus on a single unit; in this specific case the Non-residential division forms the main unit of analysis. In turn, the main unit consists of multiple, embedded sub-units of analysis. Figure 2.3 graphically shows the multiple levels of analysis and how the case, main and sub-units relate to each other.

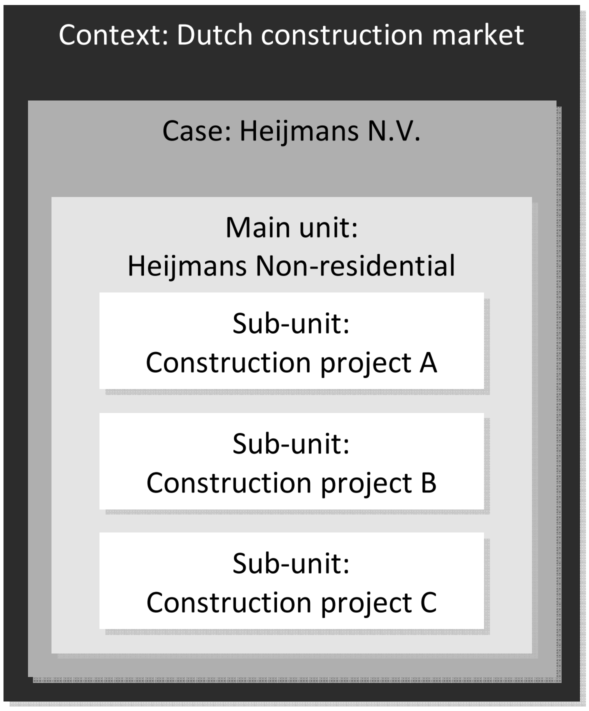

Figure 2.3: Multiple levels of analysis in the single embedded case study

2.2.1 Construction project selection

Conducting this case study requires the selection of cases within the main unit level, serving as sub-units of analysis. As mentioned, the main unit level is Heijmans Non-residential, hence the sub-units consist of the construction projects developed within this division. This selection is bound to three criterion, based on an earlier internal case study conducted by Bas Mertens (2012), to ensure variety. The first criterion is the vertical integration, indicating the extension of the core business towards DBFMO and every possible formation of these project phases. However, within this criterion the main focus remains the actual construction (B). The second criterion covers the horizontal integration. Non-residential projects encompass construction, electrical installation and mechanical installation works. Projects differ in the formation regarding these works, covering one specific, a combination of two or all three works. The third and final criterion is the current status. Along the runtime of a project new insights regarding risks might surface whereas others are mitigated. Hence, the selected cases should reside in different phases. The final selection is limited to four cases to maintain sufficient grip due to the supportive nature of the case study. Table 2.1 shows the four selected cases and their coverage of three criteria.

Table 2.1: Final selection of cases and their coverage of selection criteria

	Vertical integration	Design (Engineer)	Build	Finance	Maintain	Operate	**Horizontal integration**	Construction	Electrical installations	Mechanical Installations	**Projects status**	Tender (Block 1)	Scored (Block 2&3)	Realized (Block 4)
Frederikkazerne ‘s Gravenhage		X	X		X			X	X	X				X
Municipal office Rotterdam		X	X		X			X	X	X			X	
Bèta campus Leiden University		X	X					X				X		
UMC St. Radboud			X						X	X		X		

2.2.2 Frederikkazerne ‘s Gravenhage

17.000 m^2 - € 30.000.000,-,-

Designed and developed within 24 months, this new barracks are compact whilst being equipped with all required facilities and integrated with the guard checkpoint. This project has been developed aiming at reducing the need of maintenance, energy and materials. The object is four storeys high surrounding a courtyard. The central entrance is positioned in this courtyard connected to the wings via walkways. This central building also houses the recreational area, the canteen and the caretaker’s office. The design decisions were made with a 30 years maintenance period of in mind. This responsibility demand early awareness of the material selection, application and shapes. In order of structuring the design process, the entire project was placed into a BIM model providing extended and faster coordination of project activities.

The process of this project was short and intensive. Fabrication and construction drawings had to be developed even though the final design was still to be approved and no permit was granted. Even the fabrication of prefab concrete elements and fully assembled bathrooms had started before approval. Rushing these activities was needed due to the six months given for the preparation phase, normally covering nine months. Setting this factor alongside the large organisation of the client, leading to a complex decision process, resulted in even more project complexity.

Different disciplines collaborated on this project development due to the integral nature of the project (EBM). Heijmans Non-residential provided the construction works, electrical and mechanical works were done by Burgers Ergon and the Bestcon (at that point still part of Heijmans N.V.) performed the prefabrication of concrete elements. The maintenance for the next 30 years encompasses all construction, electrical and mechanical works.

2.2.3 Municipal office Rotterdam

42.250 m^2 - € 100.000.000,-

The Rotterdam municipality commissioned an integral project encompassing demolishment, construction, renovation, electrical and mechanical installations. After levelling the office building originating from the seventies and stripping of the monumental *Stadstimmerhuis*, the project starts with a subterranean car park. The ground floor will consist of commercial facilities, followed by four floors of office space, the fifth floor is half office space half apartments and all floors above are apartments. Part of this program is placed inside the renovated object, the rest is newly constructed after the design of architecture firm OMA. This design consists of two pyramid-shaped structures based on a modular building system ensuring flexibility in future usage. The shape reduces the shadow load on the surrounding buildings whilst creating surface for rooftop greenery. Two atria, linked to a heat-cold storage, provide an internal system capable of regulating temperature and ventilation. The façade is constructed with integrated sandwich panels made of glass with nano-gel.

Heijmans scored this integral project (DBMO) and was requested to change the provisional design into a definitive followed by a realisation design. This design process and the following realisation was performed in an integral matter between Heijmans Non-residential, Heijmans Real Estate and Heijmans Residential building. The internal installation division (at that point in time still Burgers Ergon) is in full charge of the installations, both electrical and mechanical. After realisation Heijmans will stay in charge of the maintenance for another 15 years.

2.2.4 Bèta Campus Leiden University

45.000 m^2 - € 40.000.000,-

Future plans of the university include housing all institutes residing within the faculty of Mathematics and Physics in a single building. The realization of this building is done in three phases of which this commissioned project is the first. This Bèta Campus project encompasses the realization of laboratories, college halls, offices and a subterranean car park. Sustainability was an important criterion for the tender. Applied design decisions to support this criterion are sustainable cold and heat provisions and energy efficient ventilation. More options could follow since the project resides in the stage of optimization.

Ensuring the level of sustainability is done by scoring the project with the BREEAM-certificate. The design achieved a 'BREEAM Very Good' score, achieving an unprecedented level for a Non-residential building with laboratory facilities. Another feature of this project is the entire development of the building plan in BIM.

Heijmans scored this project not only based price, but also by achieving high scores on quality aspects such as approach and organisation, control measures, reduction of hindrance, sustainability and proposed technical optimizations. Heijmans will take care of all construction works, electrical and mechanical installations were granted to another party.

2.2.5 UMC St. Radboud

15.000 m^2 - € 10.000.000,-

Redevelopment of existing real estate is becoming an important tasks for hospitals in the near future. UMC St. Radboud's redevelopment of building 'A' is an example. This building originates from 1953 and was requested an overhaul regarding the installations and interior. After redevelopment the building will contain offices for the organizational staff, a restaurant for personnel and the hospitals dialyse department. These functions are divided amongst eight floors; the ground floor is filled with the dialyse department, the restaurant on the first floor, followed by five floors of offices topped by an installations floor. The technique is aimed at both energy efficiency and creating a healthy indoor environment supporting maximum comfort levels for patients and users.

The project encompassed the optimisation of the commissioned project after scoring, verification of optimisation in preparation and realisation; all activities were conducted in construction team context. The works focussed on the electrical and mechanical installations, because of the redevelopment nature no major construction works were required. Unfortunately, Heijmans did not score this project, hence the RMO is based only on the tender product.

2.2.6 Data collection

Studying the performance of the current RMO is the aim of this case study. Due to this aim, filled RMO's of the four selected projects are the main input of this analysis. These RMO's are reduced into a single overview, allowing for a simplified insight. Judging the performance is done by statistically analysing the number of identified risks, opportunities and their characteristics per project. Alongside the enumeration, the most influential risks will be assessed on a more detailed level to gain insight in the perception of these risks among the users of the RMO's. Through a cross comparison the difference and similarities between the RMO's can be identified.

2.2.7 Case study outcomes

Statistical analysis led to an overview of the number of identified risks, opportunities and combinations, shown in Appendix A. The diagram In Figure 2.4 depicts the identified number of risks and opportunities for each sub-unit of analysis. For further comparison, Frederikkazerne has been left out due to relative low number of identified factors.

Several notions can be made when comparing the figures in the diagram. The first and foremost is the emphasis on risks. Even though the process allegedly has an equal focus on both risk and opportunity identification, more risks are identified in each project. Hence, the risk-opportunity ratios (in which risk/opportunities are account for as opportunities) are favourable towards risks. Stadskantoor Rotterdam and UMC St. Radboud show a comparable ratio. Bèta campus has quite a large gap between the two elements, but this might be explained by the phase in which the project resides. Now the project is scored, optimizations and dialogues with the client might lead to the identification of more opportunities.

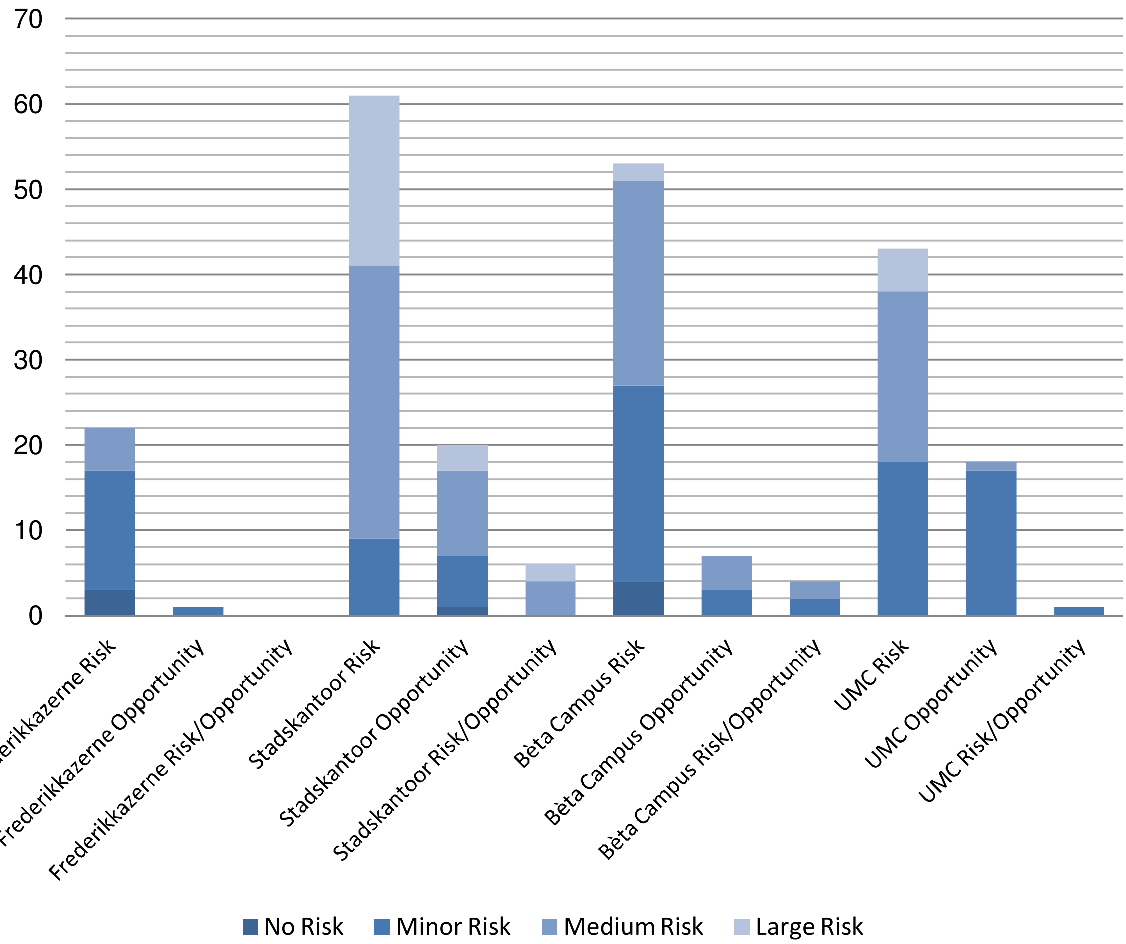

Figure 2.4: Diagram showing the number of identified risks, opportunities and risks/opportunities, including probability

With the focus on integrated contracts comes an increase in responsibilities and liabilities. The outcome of the case study confirms this trend. Even though the analysed RMO for Stadskantoor Rotterdam is a compilation of the most influential risks and opportunities stemming from underlying topic-based RMO's (nine sub-RMO's covering over 260 identified items), it shows the highest number and largest risks identified. With a tender covering four months and a preparation phase of one year, it shows that even in a limited time span (for comparison the tender phase of a DBFMO could well cover one year) conducting RM can provide an extensive identification.

A remarkable notion when analysing the different RMO's is the deviations of each RMO tools structure compared to the original tool. In the UMC St. Radboud RMO appointing ownership of risk was omitted, on the other hand a checklist was added to keep track of the completion of each measure. The Bèta campus RMO is nearest to the original, the only deviation is splitting the cost of the remainder risks among the two project parcels, construction and installations. For Stadskantoor, the RMO got extended. Not only are risks qualified based on the GOTIKV elements, but also in which phases manifestation is to be expected. These personal user alterations could provide input for the redevelopment, simultaneously the renewed method should be simple in usage to prevent users from making such alterations.

2.3 User feedback

Besides the statistical analysis comprised of the single embedded case study, user experience is gathered as feedback on the current method. Interviewss were held to gather and compile these experiences. Through questions on the subject of RM, the process of gathering can be directed to obtain the desired information. Creating a holistic insight means compiling experiences within a wide scope. Due to the desired scope-width, three people with different positions were approached for an interview. As first Frits Dirckx, risk manager and project leader, was interviewed. The second interview was held with Yvette Naaijkens, commercial and tender manager, also in charge of a workgroup regarding the implementation of System Engineering (SE) with the Non-Residential division. Martin Schellekens was the third to be interviewed in his position as bid director at Heijmans PPP (Public Private Projects). This selection was made to cover the commercial and tender phase of the process from two points of view, together with the internal transcendence of phase and information after scoring the tender.

In order of extending the experience based findings, information gathered during workgroup meetings is added to the compilation. This workgroup is actively involved in the redevelopment of the RM. Information gathered during meetings is structured into memo's from which the applicable information can be distilled.

2.3.1 User experience

Frits Dirckx (Appendix B.1) identified both strong points and points of improvement regarding the current method. Forcing tender teams to work with the RMM ensures an early identification. Once gathered information can be communicated to the teams in charge of the preparation and realization. The methodology facilitates and implemented this improvement in communications. Aside from an improvement in communication, RM also led to an improvement of information quality. By more extensive mapping of the clients expectations, a project specific approach can be developed and implemented. Measures, based on the GOTIKV elements, can be steered due to this approach. Simultaneously, realising these expectations requires concessions regarding design solutions. These concessions however are discussed poorly, leading to inadequate solutions which in their turn result in new risks. Although internal communications improved due to RM, external communications still lack resulting in a new source of risks. Emphasis on this point is needed due to the increasing use of EMVI-requisites in commissioned tenders leading to increased and more specific expectations.

Another development indicating the need for improved external communications is the shift towards Design & Construct contracts and Integrated contracts. Project management based risks and subsequent responsibilities shifted from client to contractor. Hence, for the contractor it becomes of importance to usurp only those risks that can be controlled with the available resources. Risks which are uncontrollable for the contractor need shifting or the contractor should retrieve additional influence on mitigation measures thus increasing the influence on risks. Risk prone demands and expectations can be altered or influenced through client-contractor dialogs.

'*Risk management is holistic, but no more than an instrument. Construction however is so complex and integral that more communication is needed to share all information.'* The current method provides this increase in, limited, communication and embeds quality in the organisation. Although the process of integration got initiated with the current method, extensive room for improvement still resides within. One of these improvements is the emphasis on opportunities over risk. In the current method many identified elements are negative in nature, stating that engaging risk prone activities lead to additional costs. Reverting that train of thought and adding focus on positive elements leads to a method seeking activities resulting in, financial and/or planning, benefits. In line with the earlier mentioned points, the latter relies on communications between client, contractor and third parties in seeking these opportunities. Whilst aiming at these improvements during redevelopment an important thought to be maintained is: *'The instrument lies with the user.'* To ensure the functioning of RM, the method and the tools, outsourcing should be avoided even between team members; every user should bear the responsibility of conducting RM.

Heijmans PPP (HPPP) fulfils an overarching project management position according to Martin Schellekens (Appendix B.2). Due to this position and the collaboration with Heijmans Infrastructure and Non-residential, HPPP relies on the RMM's as used in the latter two divisions. RM is a knowledge intensive process, thus relying on the knowledge regarding DBMO-components within the two divisions. Working with different methods also counteracts the efforts towards integration, thus hinting towards a concern wide RMM.

When redeveloping RM, the most important questions are regarding *what, when and who*. *What* partially points to the method itself, currently based on the RISMAN method. The latter is a functional and suitable method to structure the process. Looking at *when*, the experiences show that traditionally RM is engaged late in the process. There is no habit of starting when the project is either commissioned or scored. Besides, there is no clear mentioning of how and when RM should be implemented in the tender strategy. Currently RM has a more predominant focus on the preparation in Block 2. However, RM should be implemented once Heijmans is selected to compete in the tender in Block 1. But what is the roll of RM in this phase? Often RM focuses on '*seeing misery*' while especially in the beginning of the tender phase the focus should be on '*seeing opportunities'*. Following this thought, RM should be used in the development and steering of the bidding strategy. However, the interactive between the strategy, RM and the following mitigation measures is not present in the current method; identification of risks doesn't add to the management of the design and the underlying processes.

Considering the roll of RM, the method should evolve over time. At first, when the project still holds extensive degrees of design freedom, identification of opportunities and risks should be aim of RM. These findings contribute to the development of a project specific strategy targeting the best and final offer (BAFO). At this point a compact tender team consisting of key-players covering all present DBFMO-elements is in charge of the identification. Over time the design is bound to more restraints, resulting in decreasing degrees of design freedom thus increasing in complexity. This complexity is caused by the increase in team members. While the design gets defined, more disciplines enter the process in order of developing discipline specific details. This also means an increase in knowledge and activities, both in need of management. At this point the aim of RM should convert to management of defined activities. Aside from the aim, every point in the process RM is a team effort; every involved member has the responsibility to engage in RM. A manager should be appointed to steer the process but not to fulfil the role of risk-manager.

Creating the group-based RM effort requires tools to support the process and make it accessible for every user; tools should create affinity and understanding, the current tool however misses this ability. Users see the tool as a burden and try to avoid it as such. This leads to limited creation of quality information of risks and suitable mitigation measures. Due to this forceful stance towards RM, the developed measures currently find no implantation in the process or project. Alongside seeing RM as a burden, the evaluating role based on the iterative process is completely omitted.

Yvette Naaijkens (Appendix B.3) identified an equal issue. In the current processes, the team is requested to document risks in the RMO, but due to a mental threshold documentation is done at the last moment or not done at all. At that moment, the tender manager's responsibility increases with addition of risk and contract management, limited shared responsibility negates the team aspect. In this current process, the tender manager has to rely on his or her own knowledge and experience. In principle, the manager could revert to the experience of risk managers creating double coverage. The latter however have their own agenda and responsibilities, only allowing for limited support.

2.3.2 Workgroup discussion

'Currently reigning within project teams is a slim amount urgency and responsibility of identifying, let alone managing, project threats and opportunities though the existing RMO'. This statement is the main notion of the workgroup regarding the current situation. This limited urgency is caused by insufficient knowledge regarding the importance of conducting proper RM and the functioning of the RMM. Due to the first cause, users currently see the method as a burden with RM as activity alongside their primary tasks. Regarding RM as additional tasks, has led to the current situation in which identification is avoided. The second cause points at the non-functioning state of the current method. The supporting tool is too complex to support the process; a clear stepwise process is missing. Because of both causes, RM is not embedded in the overall process.

2.4 Empirical Comparison

Conducting RM is not limited to Heijmans Non-residential, different divisions within Heijmans have been conducting RM based on their own method resulting in practical information. Feedback can be drawn from that empirical information, resulting in possible recommendations, additions or alterations. Retrieving that information requires a study of the methods as used by the different divisions.

2.4.1 Multiple embedded case study

Performing the study is done using a combination of a single and a multiple embedded case study (Yin, 2009). In reflection to the earlier performed single embedded case study both the context and the case are maintained, thus indicating a single case study. The deviation in this study resides in the main and sub-units. Rather than one, this study will encompass multiple main units, each containing a single sub-unit. These combined levels of analysis and the relation between these levels are graphically shown in Figure 2.5. After studying each main and subsequent sub-unit of analysis individually, a cross-case conclusion can be drawn providing possible modifications. The individual studies will be limited to analysing the provided method and documentation together with supporting interviews. Providing the information for the cross-case comparison is the main target.

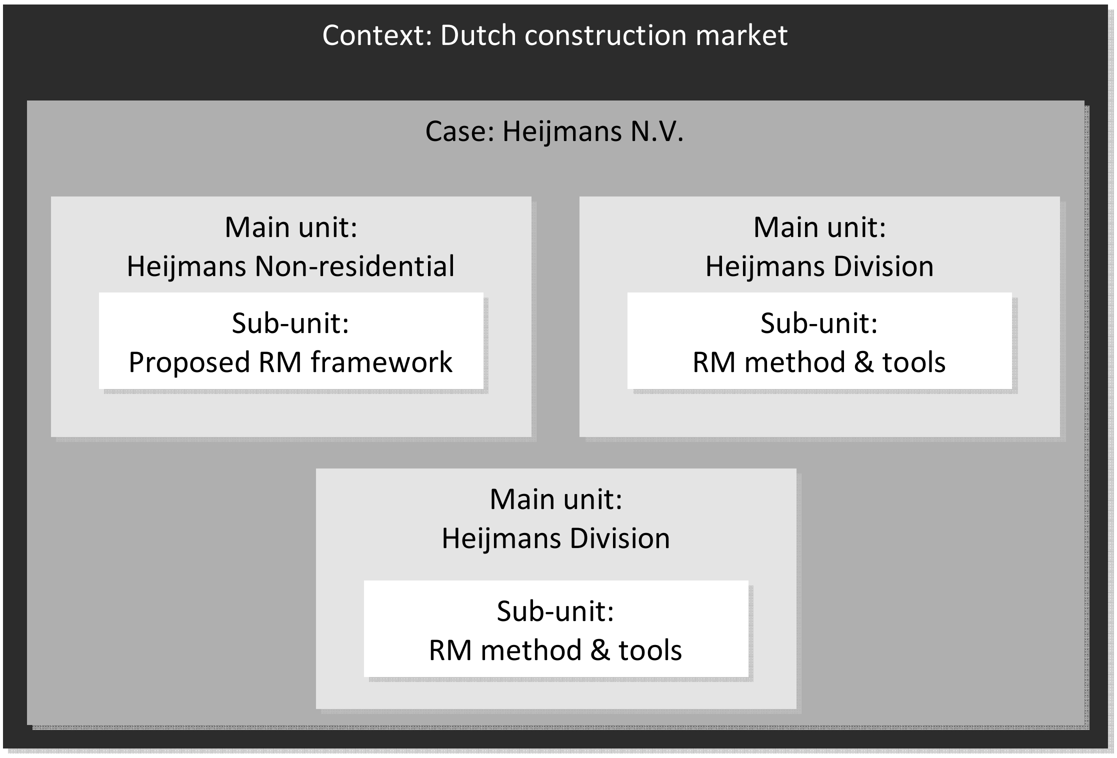

Figure 2.5: Multiple main and sub-units of analysis embedded in a single case study over multiple levels (Yin , 2009)

2.4.2 Division selection

For the case study two divisions other than the Non-residential were chosen. The first is the infrastructural division with emphasis on branch performing integrated projects, indicated by the abbreviation HIGP (Heijmans infra geïntegreerde projecten – Dutch). RM has been part of the internal process for several years and their method served as basis for the initial method of Non-residential. Additional emphasis is placed on the method and the tools due to the focus on integrated contracts; experienced regarding the extended core business should be translated to the Non-residential method, proposed framework and to be developed tools.

As second, Heijmans' Real Estate division is selected as main-unit. Besides a focus on urban development instead of the actual realisation, RM is the main focus in every project. Because of the long-term nature of projects, their development encompasses many uncertainties over time. The management of these uncertainties relies on RM, effectively making RM the core-business instead of RM being part of the core-business.

As depicted in Figure 2.5, the third main-unit is Heijmans Non-residential, the target division of this research. Naturally, this division is added to import the proposed framework into the cross-case comparison. The comparison will be conducted based on the identified factors, renewed definitions and the proposed framework, no additional information is added in this chapter.

2.4.3 Risk management HIGP

The division HIGP describes RM as *'the continues systematic research of a project for possible uncertain events in terms of time, money, quality, safety and environment, combined with implementing measures to negate or control negative effects of these events and to seize or increase opportunities'.* This description is translated into the following targets of RM:

- Gaining insight in the most important opportunities and threats;
- Develop strategies and measures to negate or reduce possible negative effects;
- Simultaneously taking steps to maximize opportunities.

The primary target of RM is controlling uncertainties through a proactive stance towards future (un)desirable events, allowing for timely actions (Kersten, 2009).

In order of achieving an applicable analysis, the Deming circle consisting of the steps Plan-Do-Check-Act is used as the management approach. This approach is applied on every aggregation level, ensuring an unified approach regarding RM. By organising the RMP over uniform, continues lines it prevents that RM is regarded as a standalone discipline with separate specialists. The risk analysis takes place during the tender and preparation phase before the start of realisation. After starting the process, RM is conducted periodically during all activities. During the analysis the focus is on specific, high risk project objects. Response measures are develop for these objects due to the proactive and preventive approach. Besides developing and steering on the measures, RM is also used to prioritize risks.

With RM being a continues process, it runs through the entire project cycle. In the tender phase, the RM strategy is developed alongside the analysis and management of all possible risks via the RISMAN method. In this phase, the RM focuses on the potential risks that can be identified during the tender or during the design phase. With the progression of the project and the increasing complexity, more risks might surface. Through trade-off matrixes, design decisions are developed for the highest risks as identified through the RM analysis. The input in this phase is based on integral risk sessions and expert knowledge. Once the tender phase is completed and the project scored, the compiled risk dossier is used as input for the realization phase. Based on the dossier, action list are provided for risk owners. These lists are then used in a four week cycle in which the action lists are provided, implemented and evaluated .Special emphasis is placed on the RMP in regular meetings and in sessions organized before the realization of specific high risk potential activities (Kersten, 2009).

2.4.4 HIGP RMP

When performing the RA, a distinction can be made between qualitative and quantitative RA. In this process, the amount of active steering is extensively based on the prioritization. To structure the qualitative and quantitative RA and the subsequent prioritization, a stepwise RM procedure is devised. The procedure's step consist of the following required RM activities:

- Risk identification: through personal interviews and risk sessions project specific are identified and documented in the risk dossier. The identification also encompasses the cause and effect, together with appointment of risk owners. Once identified the risks are coupled to an object in the system breakdown structure (SBS) in the System Engineering (SE).

- Risk prioritization: Gaining more insight in the potential risk impact, requires the determination of the initial impact through a semi-quantitative risk assumption. The risk probability is multiplied with the sum of the assumed impacts of the GOTIKV aspects. The resulting risk scores are used to assess the urgency of developing a response measure and a to prioritize the risk based on a cross comparison of the scores.
- Development response measures: Suitable response measures are developed for the highly urgent or unacceptable risks, based on scores, through personal interviews and risk sessions. These measures adhere to two natures and four different types; measures are deployed in a preventive or corrective manner and can be used to avoid, reduce, transfer or accept the risk. The selected measure is also appointed to the adjunct object (SBS) or action (work breakdown structure – WBS).
- Selection and implementation response measures: Once response measures are developed, the respective risk owner obtains the responsibility further defining and implementing the measure. Additionally, the owner is also in charge of monitoring the effectiveness of the measure. Status is added to indicate the measure's status of progression, being '*in consideration, to be practiced, no implementation, being implemented, completely implemented'.*
- Evaluation of response measures: After the implementation of the measures, the risk profile should have reduced. The actual effectiveness can be determined by comparing the situation before and after implementation. The risk that remains, remainder risk, is also documented to assume the required budget to cover the risk after the measures are implemented. At the end of the process, this very process itself is evaluated to judge its functioning through the process. Found risks are translated to a risk checklist to serve as basis for future projects' risk dossiers.
- Reporting: During the above activities, all findings are continuously documented and reported. At the basis of this reporting lies the risk dossier.

This procedure is based on the qualitative RA. Per project, a consideration can be made if the procedure is to be extended with a quantitative RA. With this analysis an assumption can be made of the budget needed to cover all combined remainder risks. The analysis is divided between the aspects money and time. Through a Monte Carlo analysis the probability, expected, worst case and best case budget or planning are estimated. All estimations are compiled based on aspect, resulting in a overall spread for the project values (Kersten, 2009). The entire procedure is shown in Figure 2.6 graphically shows this procedure. In order of creating an iterative process, an actualisation is added to renew the input based in the feedback gather from the deployed process.

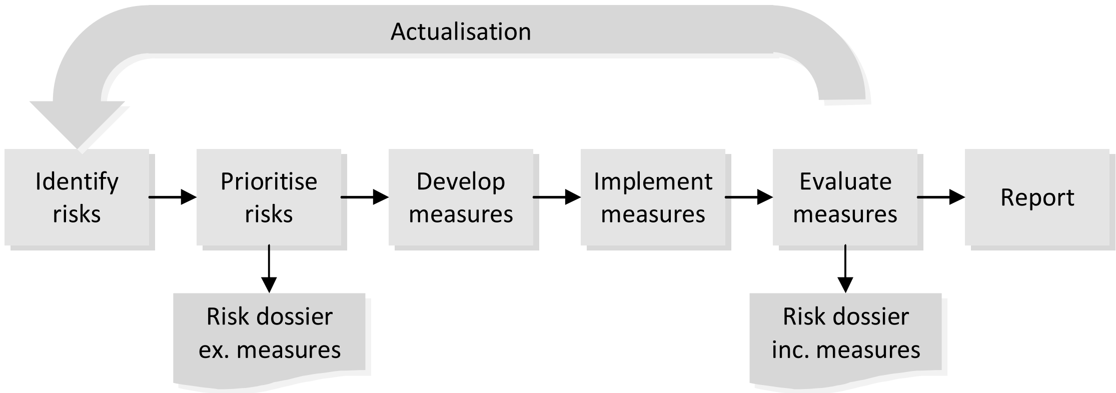

Figure 2.6: HIGP RM procedure and steps, the iterative process is placed in the actualisation (Kersten, 2009)

2.4.5 Risk management Heijmans Real Estate

Identifying risk early on during the process of real estate development is a necessity to create the ability of responding to risk manifestation. To support this process, Heijmans' Real Estate division created a practice based tool during the development of the GZG project. The tool serves a stepwise process consisting of five steps, being:

- Risk Identification: Stating the possible risks that could influence the project together with the typical project phases in which the risk could manifest. Supporting the identification is a categorization of possible risk-fields divided amongst three distinct levels, macro-meso-micro;
- Risk analysis: Describing the nature of the risk, together with the cause, effect, actual status and developing a fitting response measure. Here the earlier used categorization remains intact to provide guidance whilst developing the measure;
- Risk quantification: each risk receives a score for its probability and effect, together with the influence on planning, final quality and the projects environment. All the scores for the effect and influences are combined and multiplied with the probability;
- Documenting and reporting: With all risks analysed and quantified, the gathered information is to be report in the form of a strategy. The documented information should cover risk, phase(s), effect, response measures and strategy;
- Obtaining approval: Once all previous steps are conducted, the report is to be opted for approval. As long as the approval is not granted, the project will not move into the next phase, effectively creating a go-no go action.

The process of quantifying is supported by tables proposing both numerical, descriptive and financial bandwidths for the different elements. Because this works with bandwidths, the process functions as a semi-quantification, like with the RISMAN method.

2.4.6 Cross-case comparison

With the analysis of the approach, methods and tools of the sub-units in place, a cross-case comparison can be conducted. The aim of this comparison is to judge the current method alongside comparable methods currently in use, providing possible input for further development regarding the framework and supporting tools; the comparison will provide a vantage point through feedback and additional input.

The most important difference is the feedback loop in the HIGP process, effectively creating an iterative process. Continuously updating the information results in a more effective and connected process; developed measures will be easier to apply through continuous adjusting to the status quo. Alongside the iteration, making the method fully applicable requires a suitable method to foresee in full quantification rather than semi-quantification based on bandwidths. The Monte Carlo simulation as used at HIGP might prove a befitting option.

On a method and tool level, the increased distinction between semi and full quantification can be used to create multiple levels of analysis. This ensures flexibility regarding the phase in which the project resides, the size of the entire project and the resources available for conducting RM. When a project is small or limited time is available, a semi-quantification might be sufficient in order of grasping all projects risks. Simultaneously, creating such flexibility creates the ability to allows assessment of all present risks rather than a selection. Categorization is used to support the identification of these risks without losing the embedded flexibility to rigid formats. Further flexibility is created by embedding an entrepreneurial approach, allowing users to fine tune the RM on the situation. If a project is worth obtaining even though not all risks are fully analysed, the acceptance level of risks can be altered to ensure sufficient resources early on in the project. The same goes for uncertain, experience based input; e.g. if a likelihood is assumed based on insufficient information, the level of uncertainty can be translated to an acceptance level, effectively creating a failsafe.

2.5 Problem identification

Through the combined results of the case study and the user feedback, the most influential factors can be identified. These problems contribute to the current status and position of RM in the overall tender process. Consecutive project phase experience an equal level of non functionality and need changes to adept to the market shifts, the source of usage however lies at the tender phases hence the specific focus.

2.5.1 Risks over opportunity

Both Frits Dirckx and Martin Schellekens identified the emphasis on the negative element of RM. The outcome of the case study endorses this notion. This problem came to being due to the traditional perception of a risk as being a negative element. Although the current method targets both risks and opportunities, the original notion is maintained due to the name given to both the method and tools. Stating a clear definition for each concepts and embedding these in all incorporated elements negates the subjective influence due to perception.

2.5.2 Limited iteration

RM involves feedback processes from the developed measures towards the original design and management of the activities including their appointed owners in the overall process. Both actions demand an iterative process in which implementation and control are continuously deployed to track the project progress. Martin Schellekens noted however that currently both actions are not executed; mere identification doesn't add to the management of the design and the underlying processes. During redevelopment, the iterative process needs a more predominant position to ensure the management aspects of RM. A good example of such an iteration would be the actualisation loop as in the HIGP method.

2.5.3 Reduced team effort

Although RM is supposedly a collective team effort, Yvette Naaijkens and the workgroup noted that such effort is currently nonexistent. User have limited knowledge of the use of the RMM. The tools to support both development and sharing of knowledge regarding RM are currently too complex for its users. Hence, creating a process based on team effort requires a uniform understanding. Only once every user fully understands the basic definitions and purpose of RM can the team focus on the actual RMP. Adding a clear tool for support structures the process and provides an uniform manner for documenting the findings. Eventually, because of the understanding, users are capable to redirect their knowledge regarding RM into the design process via the mitigation measures. Simultaneously, uniform understanding allows for increased internal communication, accelerating the development of knowledge regarding RM.

2.5.4 Shortcoming strategy

Even if the functioning of the RM is improved after redeveloping the above problems, RM should not be performed for the sake of performing. None of the feedback sources indicate an overarching strategy describing the purpose of RM. Current changes in the market require more focus on developing project specifics which perform according to, or even outperform, the clients expectations. By developing a strategy, RM can be deployed in order of identifying specific opportunities and risks adhering to these expectations, allowing result validation. External communications improve as well by providing the client only with relevant outcomes, thus narrowing the amount of conveyed data. This is further enhanced by the splitting the overall process into a production (analysis and implantation) part and the entrepreneurial approach. The latter will provide the managerial based grasp on the entire process.

2.6 Conclusion

The current method for RM and the subsequent tool are not functioning as intended. Through a single embedded case study and the analysis of user feedback the problems causing this malfunction were identified:

- No equal focus on both risks and opportunities;
- Limited iterative process, developed measures are not put into use;
- Due to insufficient knowledge users are incapable of providing a uniform team effort;
- Without an overarching strategy, RM holds no predefined purpose.

These identified problems form the basis for the following in-depth research aiming at improvement or redevelopment. Each problem will be addressed to create a suitable solution or alteration in order of achieving the desired state and usage of RM. Through a stepwise process the problems are addressed and the solutions validated via empirical comparison and validations. In the following chapter the first in-depth research will be a literature study regarding the definitions of different RM concepts.

3 Risk concepts and definitions

In the current RM the emphasis is placed on risks as a negative entity instead of a supposed equally divided perception between risks and opportunities. Redeveloping or creating Heijmans' risk management anew requires an understanding of the basic concepts. Stating clear definitions negates the subjective perception of these concepts. In this chapter the definitions of the concepts involved will be assessed. This assessment is based on literature studies and involves the gathering, analysing, comparing and selecting of applicable knowledge. The target is to obtain applicable definitions of these concepts serving a basic understanding and stimulating a positive perception.

3.1 Risk definition

According to the definition of the term risks in project management (Chapter 2.1.2) is the term risk explained as '*Engaging in activities bringing about the possibility of adverse influences on the project's objective, resulting in increasing cost, project planning overrun or even the inability to complete the project.'* In this definition notions of adverse influences, increasing costs, planning overrun and the inability to complete all depict risk as a negative entity. However risk in project management and RM have been the subject of many previously conducted studies. In these studies, multiple definitions are provided, explaining risk simply as a possibility on the manifestation of an event with either a positive or a negative outcome. The literature adhering to these studies is researched to gather these definitions. Once obtained these definitions are compiled, analyzed and judged to formulate a single definition most suitable for this research. Among the many studies regarding risk management, the most common definition of risk proposed by for instance Jaafari (2001), is <u>the exposure to loss or gain</u>. This exposure in turn is described as <u>the probability of occurrence of loss or gain multiplied by the magnitude of its impact</u>. Probability ranges from 'certain events' with an occurrence rate of 100%, to events with a non-occurrence rate of 0%. Uncertainty indicates the varying probability of occurrence of events in the range between these two extremes (Jaafari, 2001). This description however contains several aspects which in turn need further defining to gain a full understanding of the description itself.

3.1.1 Uncertainty

According to Jaafari (2001) is '*project uncertainty the probability that the objective function will not reach its planned target value'*. Objective functions indicate target values which represent the project and can vary amongst different projects. However, each project is subject to meeting a particular specification, within an overall timescale, and within an overall cost (Williams, 1993). The effort of achieving these functions is influenced by project variables. If these variables remain unchanged during the process it would allow for the estimation of project risk and the subsequent probability. However, due to the stochastic and often dynamic nature of these variables, the identification of the variables themselves, their probability, impact and inter-relationships is difficult (Jaafari, 2001).

When examining the sources of uncertainty, the highest level of aggregation as done by Van Asselt and Rotmans (2002) distinguish two sources being 1.) variability, and 2.) limited knowledge. The latter indicates uncertainty based on incomplete or uncertain information due to limited resources to obtain empirical information. This results in a state in which knowledge is limited, either because the knowledge itself is bound to limitations or the perception is limited due to inexactness, lack of effort or several forms of ignorance. Hence for analysts performing research, limited knowledge is a property inherent to project development (Van Asselt and Rotmans, 2001). Van Staveren (2009) substantiates this by stating that '*even when information is perceived as complete, uncertainty is present. In addition, more knowledge doesn't automatically generate less uncertainty*.'

Variability is the most common source for uncertainty and indicates that a system or process can behave and be valued in several, distinct ways (Van Asselt and Rotmans, 2001). Jaafari (2001) indicates three principle sources for uncertainty that fall under variability: external factors, shifting business objectives and poorly defined methods for project realization. External factors encompass stakeholder requirements, institutional legislations, commercial and competitive pressure and socio-political norms. This indicates a functioning of the system in a wider context with subsequent interdependent influences. Realizing the project with poorly defined methods is partially due to the afore mentioned limited knowledge and also due to complex, non-repetitive nature of projects. Nasirzadeh et al. (2008) endorse these sources by identifying the extensively complex and large risk structure. This structure arises from multiple interdependent components affecting their overall impact internally through various cause and effect feedback loops; and the existence of external interactions between different risks that may escalate the overall impact of a risk due to the indirect and secondary effects caused by other risks.

3.1.2 Probability

Uncertainty becomes a risk when a probability is assigned to it, as is stated by Carlsson et al. (2005). Probability however is often narrowly interpreted as being a mathematical term (Van Staveren, 2009) indicating that probability is described via a numerical value. Due to the often qualitative nature of risks, developing a numerical value is difficult task often based on empirical knowledge. Therefore, Van Staveren (2009) choose to introduce the term *likelihood* based on its close relation to probability and '*it refers to the chance of something changing*'. Its broader definition allows for descriptive analysis in which the chance can be defined via objective measurement, expressed in frequencies and mathematically derived probabilities or subjective estimations by classifiers such as likely-unlikely.

3.1.3 Theoretical vs. Practical

In theory the indicated risk definition means all risks within the project scope can be identified and scaled, ensuring an adequate resource coverage and mitigation actions based on their likelihood and impact. However, multiplying the likelihood and impact results in a numerical value that could be equal for risks of different likelihoods and sizes of impact. The value of a very low likelihood and a very large impact could be equal to that of a risk with a very high likelihood and a very small impact (Van Staveren, 2009). Theoretically this multiplication proves a suitable approach to prioritize the remediation measures. In practice this assumption is not applicable when developing a project and especially when designing a construction project. Different risks require different design elements, even when the numerical, qualification values are equal after multiplying the likelihood and impact. Hence in practice the likelihood and the impact should be assessed separately when defining a fitting design remediation based on priority.

3.1.4 Dynamic character

RA includes the retrieval of likelihood and impact of the risks involved in the project. Such an analysis is often conducted once, leading to a one-time, static risk description. This single state description is the result of a missing iterative process foreseeing in continues management of the identified entities and their mitigation measures.

Risks are subject to changing variables over time, resulting in a structure with a dynamic character. Van Staveren (2006) acknowledges this dynamic nature by indicating a dual contingency model. First, risk is dependent on ever changing external circumstances consisting of factual and objective factors. Second, internally the system is depend on human perceptions consisting of interpretative and subjective factors. This external-internal influence was identified by Nasirzadeh (2009) as a source of variability. The internal structure arises from interdependency of factors through feedback loops and the external interactions between different risks results in a dynamic system in which a single changing factor could influence the entire structure.

Changing factors and views alter the manner in which the risks, their likelihood and impact are perceived over time. Subsequently, the remediation measures deployed to control or mitigate risks might need altering due to the changing risk definitions. This in turn indicates the necessity for dynamic, cyclic (returning) risk management over static risk analysis (van Staveren, 2009). Simultaneously, the cyclic process indicates the need of implementing the developed mitigation measures in the design process and validating their performance alongside the clients expectations. Only if both feedback elements are provided, is the process to considered as cyclic and iterative.

3.2 Opportunity definition

Exposure to loss or gain are both regarded as risk. As a term however, risk is often interpreted as a *threat* to the project's objective functions, the likelihood of a negative occurrence. This negative perception is only partially true. It is also possible to achieve a positive occurrence, aiding the achieving of the project's objectives. This positive risk is indicated by the exposure to gain, in other words an *opportunity*. Opportunities function in the same manner as risks, they have a certain likelihood of achieving the desired result whilst being influenced by internal and external factors.

Instead of merely minimizing the project threats, the effort should be made in identifying and achieving project opportunities. Edwards and Bowen (2005) support the concept of opportunity management, but simultaneously state that negative risk remediation shouldn't be replaced with achieving opportunities. Rather than functioning as a replacement, opportunities are an extension to the risk concept. Hence, the subject of the research will remain to be risk, but with the inherent opportunities and threats (OT) from this point forward.

3.3 Renewed risk and opportunity definitions

Compiling the above notions regarding the features of risk and opportunities leads to renewed definitions. The foremost conclusion is that both the initial definition and negative perception of the concept risk are no longer applicable. Through the notions the following definition is devised for the concept risk:

> *"Risk* is the likelihood of occurrence of either an opportunity or a threat leading to loss or gain, together with the consequences of that occurrence at a certain moment in time."

Considering this definition '*risk'* refers to the likelihood of occurrence. This occurrence in turn can be either an opportunity or a threat. The former indicates a positive occurrence and the latter a negative one, leading to the following definitions regarding these concepts:

> *"Opportunity* is an event resulting in a positive influence (gain) on the project's objective functions in case of occurrence; if assigned a likelihood, the occurrence becomes a risk;

And

> *"Threat* is an event resulting in a negative influence (loss) on the project's objective functions in case of occurrence; if assigned a likelihood, the occurrence becomes a risk."

Actions taken to realize an opportunity have a likelihood of succeeding, measures can be taken to increase this likelihood and thus the occurrence. Alternatively, in case of a threat these measures are taken to reduce the likelihood of the occurrence. Risks are composed of both these two concepts, therefore the concept '*risk'* is interchangeable with '*opportunities* and threats'. Due to this dual nature, the risk now covers the perception of both positive and negative entities.

3.4 Risk management and analysis

Creating such measures and thus controlling the project risks requires a structured process. Elkington and Smallman (2002) divided this process into two elements being the principles of 1) RA, and 2) RM. These two principles are endorsed by Van Well-Stam et al. (2003) who divided the process into the analysis of risks, RA, and controlling the risks, RM.

3.4.1 Risk management

The first and dominant principle is RM. Both Van Well-Stam et al. (2003) and Van Staveren (2009) explain RM as *'the total of coordinated activities to direct and control a project organization with regard to risk'* (Chapter 2.1.1). Jutte (2009) extended this definition by indicating a stepwise approach aiming to first gain insight in the risks followed by selecting befitting response measures. Once completed, the developed measures are implemented in the project management. However, due to the dynamic nature of risks, the original measures could be applicable on '*a certain moment in time*' and inadequate shortly after. Monitoring and evaluating is required to continuously redefine the response measures and their influence. Due to this continuous nature, the structure of the RMP needs to be cyclical, providing the ability to engage the subsequent activities in an iterative manner (Van Well-Stam et al., 2003; Van Staveren, 2009). Combining the two literature based definitions and embedding the cyclical structure resulted in the following definition:

> "*Project risk management* is the systematic design, implementation and monitoring of activities in a cyclical structure providing a continuous, iterative process to identify, prioritize and analyze project risks and to devise, select and implement responses to optimize these risks."

3.4.2 Risk analysis

Risk analysis (RA) is the second principle and is '*designed to pick up and gain detail on both business and project risks*' (Elkington and Smallman, 2002). Van Well-Stam et al. (2003) altered this definition into a generic and applicable statement by defining RA as '*the process of systematically gaining insight in the project's risks and developing risk response measures and their subsequent effects*'. Picking up and gaining insight on risks points out the identification and analysis of risks together with their cause, impact and likelihood. Combining this notion with the two statements results in the following RA definition:

> "*Project risk analysis* is the process encompassing the activities required to identify, prioritize and analyze the cause, impact and likelihood (characteristics) of project risks and to develop measures aiming at the optimization of these risks."

When comparing the RM and RA definition, an overlap is noted in the activities. RM requires the analysis of project risks in order of developing applicable response measures, RA foresees in this analysis with focus in the project risks' characteristics. RA is performed as the initial analysis at the instigation of the RM, thus rendering the RM depended on the RA. Although the functioning of RM is reliant on RA, the former is the dominant of the two principles. Where RA displays a single, static analysis process, RM is performed continuously; once the RA is performed during the tender phase, RM is deployed for all following phases depend on the contract form. The latter means that in case of a DBFMO, RM is preformed during the preparation, realisation, maintenance and the entire operative lifespan. The RM also encompasses the actual implementation and monitoring of the response measures. This is supported by common, practical usage of the term RM.

When developing the response measures multiple options are available regarding the measure's target. This target is based on the risk's characteristics e.g. the extend of impact; if an opportunity has a large impact, the target could be to achieve the highest possible likelihood. The targets display differences between opportunities and threat, but share common elements providing the following options (Elkington and Smallman, 2002):

- **Promotion/prevention**: through the developed and selected response measure opportunities are solidified whilst threats are prevented from arising or their effects are nullified, thus making the risk a certain event;
- **Increase/mitigate**: when achieving a certain event is not possible, the likelihood can still be increased for opportunities to increase the level of influence, and mitigated for threats limiting the influence;
- **Obtain/transfer**: opportunities might reside with third parties, obtaining and incorporating them in the internal process increases the influence, certain threats might however be beyond internal control and are transferred to third, capable, parties;

- **Contingency**: although the risk is foreseen no immediately actions are taken, the response measure is to be developed and the required resources set aside till the moment either opportunity or the threat arises.

3.5 Conclusion

The traditional perception and explanation of the concept risk proved to be inapplicable. Risk merely indicates the likelihood of an event occurring, regardless of the nature of this event. If the event results in a gain for the project's objective function, it is called an opportunity. In the case the event results in a loss for the project's objective function, it is called a threat. If combined, '*opportunity and threat'* are interchangeable with the concept 'risk'. Because of the dual nature, henceforth this renewed definition for '*risk'* is leading in this research. It is stressed that in any form of implementation or communication these definitions are explained first to ensure a uniform understanding amongst the users or other parties involved with RM.

Whilst managing a project, opportunities are to be seized and threats mitigated. Providing the control on the activities capable of doing so, requires the RA and RM processes. RA foresees in the process-based activities needed to obtain all information regarding the cause, impact and likelihood of project risks. Based on this information, suitable response measures are developed to promote opportunities and mitigate threats. RM is the systematic implementation of the response measures. Due to the dynamic nature of project risks, RM adheres to a cyclical structure to provide a continuous, iterative process.

3.5.1 Research progression

RM indicates the management of both threats and opportunities influencing the project's objective functions through the response measures developed during the RA. This management consist of several activities which are to be structured into a framework. Embedding these renewed definitions into the framework ensures their usage in RM and allows the users to steer the process towards the management of positive and negative entities. In the following chapter the framework is constructed with additional attention for the creation and embedding of an iterative process. With the latter, the dynamic nature inherent to risk is covered by the framework.

4 Risk management framework

In order of structuring the RMP and the necessary activities, a framework is devised. Embedding the renewed definitions regarding concepts involved with RM provides direction for these activities. The framework should foresee in the ability to implement actions developed to either promote or prevent risks, requiring an iterative process providing for continues feedback. The developed definitions are used to create an outline for the framework. Through literature studies and cross-comparison the market's current and prevalent methods are assessed to obtain applicable elements for the framework. The main thought is to create a process that provides information regarding the identified risks in an increasing manner. With the outline in place, a structure can be devised and in turn, activities are identified and assessed. Suitable activities are selected from the assessed methods and placed in the framework, resulting in the proposed RM framework (RMF).

4.1 Risk management process

Leading for the outline are the RA and RM principles and their definitions; RA foresees in the risk-based component, whilst RM covers the response-based implementation component. The RM definition indicates the need for RMF capable of providing the systematic design, implementation and monitoring of activities proposed by the response measures. The individual and combined aspects of this definition and that of the RA serve as requirements for the development of this framework and the integrated elements. Since RM and the underlying RA are based on a set of coordinated activities, the entire set of activities can be explained as a RMP. Jutte (2009) stated that '*RM is a systematic process based on a structured method to deal with risks, including clear responsibilities, priorities and tasks*'. Many studies devised such a structured method and although a universally agreed process definition does not exist, many of these definitions share common elements. Studying and comparing these methods provides a selection of applicable elements for the framework.

4.1.1 RM methods

In many studies such as those by Jaafari (2001), Tserng et al. (2009) and Nazirzadeh et al. (2008), the applied method is the process as proposed by the PMI (2000). This method holds a preference because of its integration in the overall project functioning and performance. Tserng et al. (2009) proved this influence on the performance by conducting case studies with the generic PMI method (2000). Although different descriptions are used for the activities, the initial outline of the method proposed by Tummala and Burchett (1999) is comparable to that of the PMI (2000). However, instead of describing a linear process, the method proposed by Tummala and Burchett (1999) separates the driver from the RMP and creates a dynamic loop for the risk evaluation and risk control and monitoring. The corporations business strategy lies at the basis of the project mission and aims; combined the identified importance, strategy and objectives form the driver for conducting RM. The actual process start by identifying all potential risks factors, the subsequent impacts, seize of impact, uncertainty associated with these impacts in the form of likelihood distributions. Van Well-Stam et al. (2003) deploy an equal approach with the RISMAN method consisting of generic steps (Van Staveren, 2009):

- Setting the objectives of the OR analysis in the context of the project;
- Identifying risk from a number of different perspectives;
- Classifying these risks;
- Identifying and executing opportunity optimization and risk remediation measures;

- Updating of the risk analysis for the next project phase.

GeoQ is a RISMAN method spinoff with a more in depth approach focussing on the geotechnical industry and extending the method by introducing the quality (Q) aspect. The latter is realized by extending the afore mentioned steps with the '*evaluation the effectiveness of the risk opportunity optimization and risk remediation measures*'. Within the method this step fits before the '*updating of the risk analysis for the next phase'* and creates a cyclical approach with a dynamic nature through the introduced feedback loop (Van Staveren, 2009). This evaluation of the performance indicates the necessity of having a functional method expressing an actual influence on the project performance, thus rising to the same level as the previously preferred PMI method (2000).

Within the RISMAN method these activities are divided amongst two process elements being 1) RA, and 2) RM. Dividing this process into two phases is endorsed by Elkington and Smallman (2002) stating that '*the process of managing risks begins with RA, which is designed to pick up and gain detail on both business and project risks.'* Their second element, RM, integrates the risks identified in the analysis into the project management. The latter encompasses the same activities as repetitively mentioned for the other methods. Eventually the information from the RA is updated based on the feedback following from this evaluation and the choice of response measures is revisited (Van Well-Stam et al., 2003).

4.1.2 Method selection

When comparing the above described methods, it becomes apparent that in each process follows a similar path running from identification, via risk assessment and response development to evaluating the results. Although these phases are similar, besides some minor variation in the terminology, a distinct difference is noted in the expression of the circularity of the processes' structures. Precisely this circularity is needed to support the dynamic character of the system, whilst providing for a continues, iterative process supporting the project throughout its lifespan. A cyclical structure is capable of creating such a process, hence the preference befalls to the process structure as proposed by the RISMAN method. Analysis and management are two different principles that are effectively separated by this process without losing the integral functioning of the RMP. With this division, the method also adheres to the outline based on the RA and RM definitions. The choice for this model is endorsed due to its current implementation at Heijmans. Mainly the analysis element is present in the current risk management. Due to its implication empirical knowledge regarding risks and the functioning of the process has been created. Considering the dependence of RM on empirical and expert knowledge, discarding all information gathered would be an inefficient attempt.

4.1.3 Method-based framework's structure

With the selection for the RISMAN method, the framework's structure can be devised. At the basis lie the two principles as denoted in the RISMAN-method, being RA and RM. The former is the initial principle, fitted into a linear process structure. The latter is the follow-up principle, providing the required cyclical process structure. The combined principles and their nature are shown in Figure 4.1. The following step is embedding the required activities into the framework's structure upon achieving the completed framework.

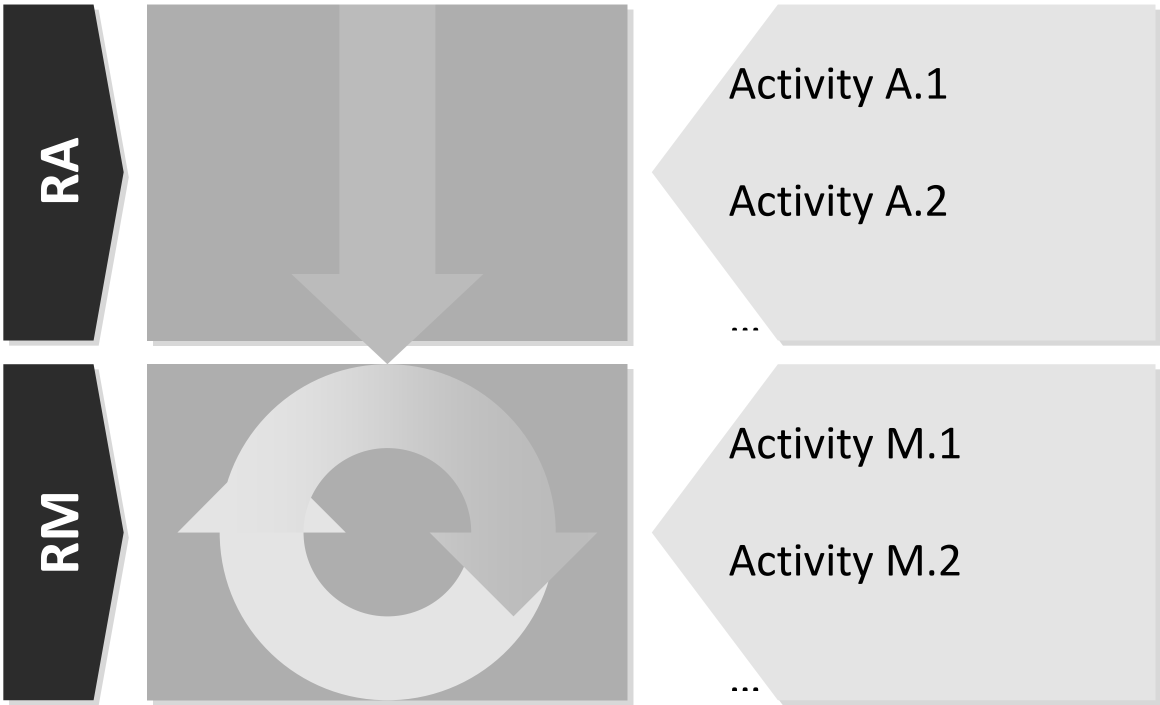

Figure 4.1: Proposed method-based framework's structure, consisting of the two RISMAN principles, their subsequent nature; Completing the framework requires embedding of the suitable activities.

4.2 RM activities

As with the methods, the different sources indentified multiple activities. Though many of these activities are comparable in essence, their definitions show minor differences in detail thus in application. In order of creating the most befitting from work, a selection is made from activities identified during the literature studies. This selection is made by cross referencing the activities from different sources.

4.2.1 Method-based activities

During the identification, the activities can be divided amongst the two principles. For the identification the same methods as for the selection of the structure are used, being Van Well-Stam et al. (2003), PMI (2000), Tummala and Burchett (1999) with the addition of Her Majesties (HM) Treasury (2004). Table 4.1 gives an overview of the method-based activities.

Within the RA principle, the method-based activities are comparable. Three out of four show the need of defining the targets of RM in either the objectives or strategy. Identification and the development of response measures are present in each method. The actual analysis is denoted differently in each method, but the qualitative and quantitative aspect return in three out of four methods. Regarding the RM principle Van Well-Stam et al. (2003) describe this process through multiple activities. Simultaneously is this the only method foreseeing in a feedback activity regarding the RA, thus a circular process. Elkington and Smallman (2002), not mentioned in the cross referencing table, deploy the same activities as Van Well-Stam et al. (2003) though with different words. They describe '*implementing and evaluating measures*' as '*planning, monitoring and controlling measures*'. This shows that the single action as provide by methods other than the RISMAN are to limited in order of covering the entire RM principle.

Table 4.1: Overview of activities as mentioned in different sources by their respective authors.

Van Wel-Stam et al. (2003) RISMAN	PMI, 2000	Tumalla and Burchett (1999)	HM Treasury (2004)
Risk analysis activities			
Identification of project objectives	RM planning	Identification of strategic importance	-
Risk identification	Risk identification	Risk identification	Identifying risks
Risk prioritization: *Includes qualitative and quantitative risk analysis*	Qualitative risk analysis & Quantitative risk analysis	Risk measurement: *Qualitative analysis* Risk assessment: *Quantitative analysis*	Assessing Risks: *Assessment of impact, likelihood, tolerability and residual risk*
Development of measures	Risk response planning	Risk evaluation	Addressing risks: *Creating response measures*
Risk management activities			
Selecting measures	Risk monitoring and control	Risk control and monitoring	Reviewing and reporting risks
Implementing measures	-	-	-
Evaluating measures	-	-	-
Updating RA	-	-	-
-	-	-	Communication and learning

Elkington and Smallman (2002) also indicate the activity of identifying and allocating resources. Implementation of response measures is based on the availability of solution-based required resources, thus resource identification is of importance. However, this activity is only required in case of unique or large demands, otherwise the required resources can be aggregated into a single budget or planning. The need for communication as mentioned by the HM Treasury (2004) is added to the process structure within the cyclical RMP. Van Well-Stam et al. (2003) already mentioned the ability of RM to '*improve the communication within the project*', however actually mentioning the action in the model creates the needed awareness. Beside the awareness, communications need to be extended beyond a single project scope. This will provide the storage and accessibility of knowledge within the organization thus providing a learning aspect. Developing such knowledge will reduce uncertainty over time by supporting the process of identifying risks, their characteristics and measures.

Within the RISMAN method, the process jumps from the risk identification straight to the prioritization seemingly omitting the analysis of the risk characteristics and measurements. This step however is paramount and should take place before the prioritization is made[3]. Several terms are used to describe this activity following the identification, such as assessing,

[3] In theory the RISMAN method encompasses this activity but as a sub-activity of the prioritization.

measuring or estimating. When looking at these descriptions and the different activities as described in Table 4.1, the selecting is made for the term ‘risk assessment’ because the activity involves multiple analyses. In turn this activity is divided into a three step procedure consisting of Qualitative Risk Analysis, Quantitative Risk Analysis (PMI, 2000) and Risk Prioritization (Van Well-Stam, 2003).

4.2.2 Research applied activities

Out of the identified activities a selection is made based on the results of the cross reference. The criterion applied on this selection is the creation of a clear process. Each of the selected activities should be unambiguous in their purpose, thus ensuring a clear process uninfluenced by subjective interpretations. Deconstructing a single complex activity into multiple, unambiguous activities also creates a basis for a stepwise process; an easy-to-use method consist of clear steps supported by tools, equally step-based.

The first activity is ‘identification of project’s objective functions’. In the cross reference, this activity was regarded as a part of the RA principle. Reverting however to the interview with Martin Schellekens (Appendix B.2), the project’s objective functions are part of the bidding strategy during the tender phase and, if scored, part of the overall project strategy during the following phase. Thus stating the purpose of RM in the strategy is an activity that is paramount to the implementation of RM overall, hence this activity is omitted from the RA principle and regarded as a ‘stand alone’ activity with regard to the RMP. Because of strategic nature, the activity becomes part of the project’s strategic development. This leaves the following selection for the activities in the RA principle:

- **Risk identification**: activity of identifying and gathering all opportunities and threats capable of influencing the project’s functional objectives, including their source and impact or ‘*cause and impact’*;
- **Risk assessment - Qualitative risk analysis**: further analysing the previously identified risks by qualifying their impact through the GOTIKV elements and appointing enumerated or qualitative bandwidths;
- **Risk assessment - Risk prioritization**: arranging the qualified risks for further analysis and development of mitigating response measures based on their combined elemental impact-scope and impact size;
- **Risk assessment - Quantitative risk analysis**: further analysing the most influential risks (based on the prioritization with a predefined, strategic set-size) creating exact measurements instead of bandwidths, possibly leading to alterations in the prioritization;
- **Development of measures**: Creating befitting measures capable of mitigating, remediating or replacing the identified threats and to increase and promote opportunities.

Structuring the process with these activities results in an initial overview crafted from the project inherent opportunities and threats. Due to the analysis not the only cause and effect have been defined, but the characteristics and their respective prioritization as well. Extending the process with an iterative partition encompasses the implementation of the developed measures and judging their functioning by evaluating the results with expectations originating from the project's objective functions. In order of creating such an iterative process, the following activities have been selected:

- **Planning measures**: selecting when to implement which measures, if combined with ownership allows for continues monitoring;
- **Implementing measures**: combining action and the required resources to ensure the implementation of the selected measure the responsible by the risk owner on their predefined planning;
- **Evaluating results**: judging the effectiveness of the implemented measure in comparison to the project's objective functions and the initial situation;
- **Updating RM statement**: using the evaluated results to update the initial outcome of the RA and the reconsider the response measures and their underlying prioritization;
- **Identifying and allocating resources**: measures can only be implemented if the required resources are present, thus requesting identification and allocating of those resources – only of importance for the largest, most influential or unique risks.

4.2.3 Activity-based products

Because each activity yields to additional information, several products are produced during the completed RMP. Following the first embedded activity, risk identification, is a risk overview (RO). This overview provides a risk description together with the cause and effect. Through the risk assessment, characterization and quantification is provide for the risks, resulting in the risk profile (RP). By adding developed control and response measures based on the information in the RP, all information on the possible risks is collected and documented in the risk management statement (RMS). Turning the gathered information into applicable actions is done by transferring the found risks and their measures to the Project Management Plan (PMP). This plan contains all measures, the action that need to be deployed when implementing the measure, who is responsible for each action and what the required resources are. Changing the information into practical applicable statements supports the implementation of the risk information whilst making design decisions. From a managerial viewpoint, the PMP can be used to assess progress of implementation; when actions have a deadline but are not performed in due time, the manager can steer the progresses by approaching the one responsible for that very action. The same goes for the control regarding all other resources besides time. Continuously updating the PMP on set intervals foresees in the actualisation of the desired iterative process.

4.3 Risk management framework

Embedding these research applied activities and their subsequent products in the method-based RM framework-structure, results in the proposed RM framework as depicted in Figure 4.2. Through this framework, the RMP can be structured to provide a clear stepwise approach ensuring that both the RA and RM principle are present. Because each activity creates unambiguous outcomes documented in multiple process products, continues monitoring is possible. The RA principle activities foresee in a linear process, resulting in the RMS. The circular process from the framework structure is provided by the feedback process arising from the RM principle's implementation and evaluation activities.

4.4 Conclusion

Embedding the renewed risk definitions and ensuring the iterative process requires a framework in order of steering the process. This framework consists of two principles, being

RA and RM resulting from the RISMAN method; aside from its current implantation, this method also allows for complete and proven integration in the overall project process. The activities embedded in the framework, are selected in order of creating an unambiguous process with a clear stepwise procedure negating perceptive subjectivity.

The RA principle, the underlying activities and subsequent products create a linear process of risk identification, assessment and response development. During these activities the equally divided focus on opportunities and threats can be monitored. The RM principle activities provide continues updates for the PMP, ensuring the iterative process nature. The proposed framework contains all mentioned elements structured in a stepwise procedure.

4.4.1 Research progression

Though the RMF proposes a process structures with a clear stepwise procedure, it still lacks the practical support for implementation in the actual project process. Creating the support for implementation requires a tool developed with the RMF as foundation. In the following chapter a suitable tool will created in which the main notions and the activities of the proposed framework are represented in either the tool or documentation. The aim should be to provide a tool capable of collecting, storing and conveying all relevant data regarding the risks in each project. Additional attention will be given to the risk inherent uncertainty and how to handel all information in a dynamic manner due to the iterative process structure.

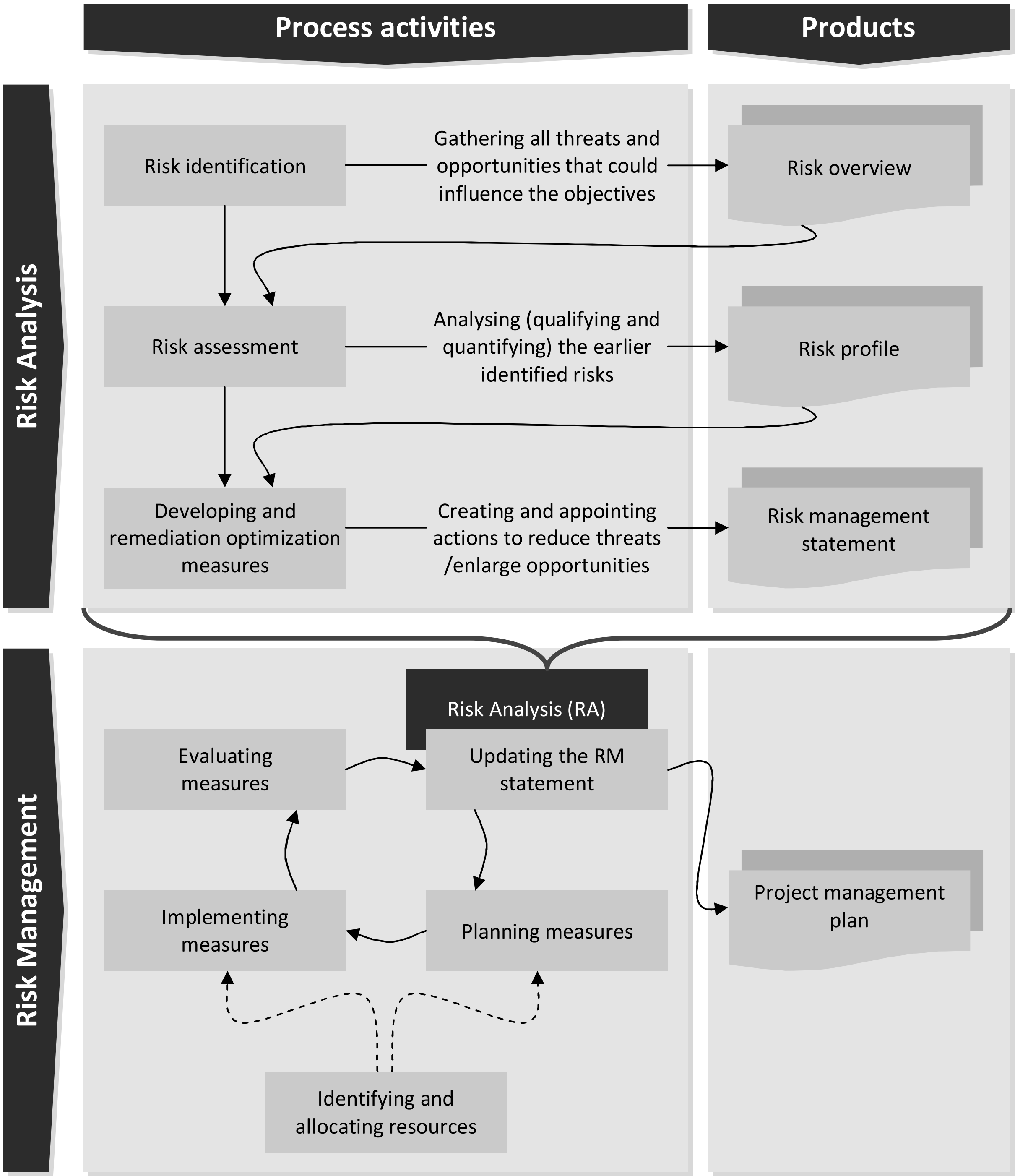

Figure 4.2: Proposed RM framework including the selected activities and products embedded in their respective RM principle; the framework focuses on the internal process, hence the overarching strategic step is, currently, omitted.

5 Framework-based tool development

Working with the proposed framework foresees in a stepwise process structure, based on the required RM activities. Engaging in the process with the activities as a baseline provides an unambiguous approach, clearly stating the purpose and aim of every step. Following the purpose and aim, information is gathered during every step with an increasing amount of detail. This information needs to be stored in an equally structured manner to prevent loss of knowledge and to promote traceability. Such a manner is provided through a tool in which the information can be stored. Simultaneously, a tool will also support and secure the stepwise process structure by indicating which information needs to be gathered to complete each step. In this chapter this tool will be developed, based on the proposed framework. The process of developing this tool is done in conjunction with the framework and the subsequent stepwise structure. With the framework as outline for the tool, the tool itself is created with suitable methods selected through literature studies with comparable subjects or applications. The main aim is to create a tool that provides the process with a simplistic structure, thus making the it understandable and applicable for every user.

5.1 System selection

Several, progressive systems are available in market such as Relatics, a semantic database capable of supporting a systems engineering (SE) approach. Within Heijmans, project engineering and development is increasingly performed using this approach. According to Kenzo Oijevaar (Appendix B.4) "*the benefit is the ability to couple SE objects to the identified RM elements. If work is performed on such an object, the underlying risk is provided simultaneously. This allows for continues verification and monitoring of this risks. Because the database is used in both the tender and realisation, the gathered knowledge and proposed actions are easily transferred between phases with minimum loss. On the other hand, Relatics is no more than a database and a tool. In essence the system in which the risk dossier is maintained as long as it actively maintained.*" The notion endorses the necessity of providing a understandable tool which can be used by every member in the team, regardless of the phase in which the project resides. In line with the aim of simplicity and creating an understandable tool, windows excel was selected as the system in which the tool is developed. On one hand this system is straight forward in its use, commonly applied and the current tool is also created in excel. Simultaneously, the system allows the creation of mathematical equations and logical operations, combined on multiple sheets providing the flexibility that might be required when proceeding from qualitative towards quantitative information and vice versa.

5.2 Tool outline

As formerly mentioned, the proposed framework and the subsequent activities serve as a baseline for the tool. Hence the tool will be developed according to the same stepwise procedure. With identification as the first step, the basic information regarding the risk is gathered; cause, impact its nature (opportunity, threat or optimization) are basic characteristics of every risk. In each following step, additional information with increasing levels of detail is gathered and documented. All information needs to be summarized to provide the RMS, conveying all relevant information both internal and external. Finally all information should be documented such that all made decisions can be traced, providing traceability. Combining these notions of gathering and documenting, summarizing and providing traceability, create an outline for the tool. Important for this outline is to emphasize the stepwise nature without losing the integration, hence the ability of creating multiple sheets is applied as shown in Figure 5.1. Most distinctive in the outline is the continuation of information; labelling as appointed in the identification is provided in every subsequent activity, ensuring that additional information is added to the correct risk and providing the required traceability. It also compiles all risk specific features into a single risk profile, which forms the RMS once measures are added.

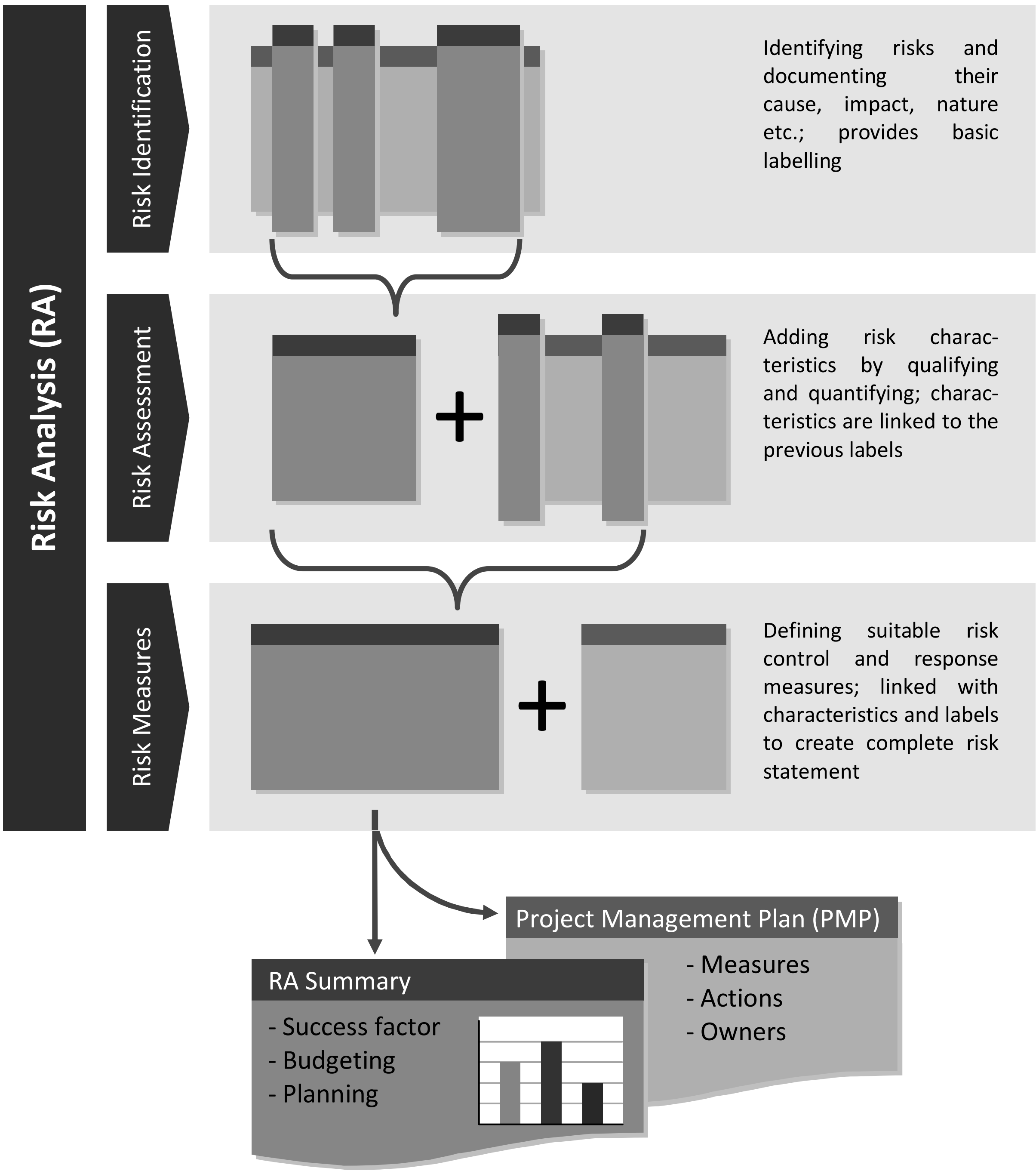

Figure 5.1: Outline for the tool with a clear stepwise structure, continuation of information providing integration and traceability and summarizing the information into two distinct outputs.

5.3 Risk identification

As has been explained in the previous chapter, risk identification is the *'activity of identifying and gathering all opportunities and threats capable of influencing the project's functional objectives, including their source and impact or 'cause and impact'*. The aim is to create a basic description, labelling each risk as a reference for the following assessments. Such a label consists of the following elements:

- **Numbering**: by adding a number to each risk, they are easily traceable, even though filtering or sorting might make them shift with regards to the original documenting. This foresees in the ability to assess the identified risk on different aspects, without reducing the dynamics or traceability of the tool;
- **Tag**: A short (two-three word long) tag creates a simple and recognizable reference, simplifying the descriptions and adding to the traceability. The thought is to create a tag capable of indicating the risk's determinant;
- **Editor**: If the description or selected nature of a risk is unclear, the best way of finding additional explanations is with the person who made the initial identification. In order of making this feat possible, the editor of the risk (this can be either the person who identified the risk or the one that performed the documentation, hence editor) is requested to denoted his or her name;
- **Description**: This is the actual risk description, including the cause and impact. Whereas several methods divided these notions into separate entities of identification, this was purposefully omitted in the creation of this model. Many users tend to have difficulties defining the cause and impact with regards to their specific risk, commonly due to vague borders between these entities. As a direct result, risk descriptions are often incomplete and lacking in quality, providing insufficient basis for the creation of adequate control and response measures. Thus it is recommendable for future applications not to split these entities but have them identified as a single entity, as with this very tool;
- **Nature**: As has been stated in the renewed descriptions, a risk can be either positive or negative regarding its impact on the project's objective functions. Hence it is important to state whether the identified risk is a opportunity or threat. A third state of nature is added to cover all ranges, being the '*optimization'*. An optimization is a proposed improvement to the design, for example replacing the originally selected material with one that is comparable but outperforms the former in terms of price, quality, environmental impact, durable or a combination of factors. Before the optimization is implemented it is perceived as an opportunity for both client and contractor. However, when the optimization is implanted without the consensus of the client[4], the optimization turns into a threat for the contractor. Prices are adjusted according to the alterations resulting from the optimization, impacting on the price of the final tender offer. If the client however turns down the proposed optimization, the contractor will most likely make a loss on having to turn back the made alterations, thus effectively rendering it a threat. Due to this '*in-between'* state, optimizations are added to the possible risk natures;

[4] During the tender phase, one-on-one communications are prohibited, applying a perceived optimization without consensus creates an uncertainty with the possibility of the client disagreeing with the alteration

- **Category**: Steering the following assessment and the development of either control or response measures, is done through categorization. Bundling risks with comparable characteristics, creating near homogeneous sets, allows for focus on specific sources and improves the efficiency of the RMP. In the previously conducted research multiple categorizations have been devised. Van Well-Stam et al. (2003) e.g. proposed two lists of categorizations of which the on the DESTEP-acronym is one, indicating demographical, economical, social, technological, ecological and political angels. Jaafari (2001) indicated categories that can typically be encountered on large projects. These categories are based on the different variable sources of risk, namely promotion, market (volume and price), political, technical, financing, environmental, cost estimation, schedule (acceleration or delay) operating, organisational, integration and force majeure. The main thought of these categorizations is triggering and encouraging every involved team member to think from multiple standpoints including those outside his or her professional scope. However, these literature-based categories are generic and can be regarded as vague. The categories should aid the overall RMP in integrated project development. Based on that notion, the categories in this research and thereby the tool are based on the different disciplines as shown in Table 5.1. Ownership can be appointed easily, creating ownership based on recognition, a notion neglected by the generic categories;
- **Status**: The status is added to explain the, initial, progression of the risk its following control and response measures. This label of status becomes of increasing importance during the RM principle phase, due to the cyclical and dynamic nature leading to possible status updates. Besides the fact that alterations to the status might affect the overall risk budgeting (e.g. optimizations being applied thus moving from opportunity to threat), it also leads to shifting prioritization when a critical risk has gone in to a 'hold' status. For opportunities and threats, the possible statuses are '*Ongoing, Completed or Hold*' and for optimizations '*To be applied, Applied or Hold*'.

Table 5.1: Seven selected categories as based on the different disciplines.

Risk category	Description
Contractual	All risks that follow from agreements on subsequent juridical aspects are regarded to as contractual
Financial	The responsibility regarding availability of financial resources due to increasing integrated contracts
Structural	Typical risks included with ground-works and the creation of the load-bearing structure
Construction	This category encompasses all risks involved with construction works aside from installations and structural
Mechanical installations	All moving installations including ventilation, heating/cooling and additional mechanical based design efforts
Electrical installations	Risks regarding a fully functional and secured electrical installation, also encompasses ict provisions
Integrated design	When a risk hinges on multiple categories, it is regarded as an integrated design risk, demanding an equal design effort

These elements are placed on a single sheet, shaped as a table and labelled as '*1. Risk identification*'. Each element is placed at the top of a column with each row presenting a single risk. For the latter three elements, the descriptions have be predefined. This limits the spread of possible answers, providing more structure whilst decreasing the complexity of defining the identified risks. These choice options are conveyed into the tool by means of dropdown menu's, a feature incorporated in excel. The benefit of using such menus is providing the users with the actual limited choice options and simplifying the documenting, all effort can applied in the actual identification rather than how to document the information.

5.4 Risk assessment

Developing effective control or response measures requires an insight in the extent of impact each risk holds regarding the objective functions. This insight is provided via the risk assessment. As mentioned in chapter 4.2.2, risk assessment encompasses risk qualification, prioritization and quantification. Qualification is '*the further assessment of the risks impact by appointing enumerated or qualitative impacts*', prioritization is '*arranging the qualified risks for further analysis and development of mitigating response measures based on their combined elemental impact-scope and impact size*' and quantification is '*further analysing the most influential risks creating exact measurements instead of bandwidths*'. These literature-based descriptions denote a process in which risk impact is roughly estimated after which only those deemed 'most influential' are quantified. This stems from the common tender procedure in which the client often desires a representation of the ten most influential projects risks. The RISMAN based methods adhere to this thought by devising such a top ten. In RM however, the aim is to identify <u>the entire impact</u> of <u>all risks</u> and <u>not a limited selection</u>. Due to such a selection the allocated resources will never be adequate in mitigating or remediating all project risks. Hence the RM approach should treat all identified risks rather than a selection: *"everything with an attached price is important"* (Oijevaar, AppendixB.4).

5.4.1 Risk assessment aim

Regarding every risk as important, requires an alteration to the inter-relational positioning of the assessment activities. An effective assessment should adhere to a specific aim, positioning the subsequent activities accordingly. First and foremost, the aim should be to quantify each risk in terms of their impact on the budget and planning. These two elements form the key-denominators for every project and simultaneously enable to judge the performance and progression of the project with regards to the set resources. Although multiple factors influence risks and their impacts, e.g. the GOTIKV-factors, all factors can eventually be reduced to a monetary, planning or combined[5] impact. This leaves two possible situations at the start of the risk assessment, either the characteristics regarding monetary/planning impact are certain or uncertain. When the characteristics are certain, or can be substantiated through research, they can be documented. This is regarded as directly quantifying a risk. However, if the characteristics are uncertain, both the qualification and quantification are required. Once all risks have been quantified, they can be prioritized based on the financial impact rather than a vague, bandwidth based qualification. The renewed positioning of the assessment activities is shown in Figure 5.2.

[5] Deviating from the planning often leads to bonuses or fines, effectively reducing them to a monetary impact, however the thought of having a budget and a planning is maintained at this point

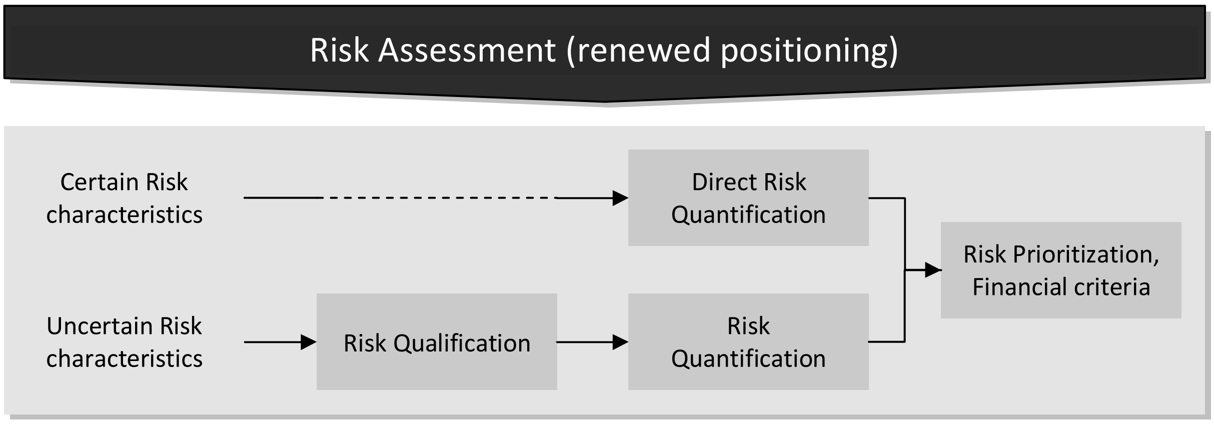

Figure 5.2: Renewed inter-relational positioning of the assessment activities, based on the aim of quantifying each risk in terms of their characteristics regarding monetary and planning impact.

5.4.2 Risk assessment with certain characteristics

As mentioned previously, if the characteristics of a risk are certain, the only action required is direct quantification by documenting those characteristics. Risk that require little research e.g. contacting a supplier, are also considered a certain risk. These characteristics are documented in the second sheet labelled '*2. Risk assessment*'. This sheet is structured in the same manner as the identification sheet. Each row represent a single risk, where each column describes a certain feature or characteristic. The first columns refer to the identification, providing the number, tag, nature and category. Added to these columns is a the 'Certainty check' with its predefined choice options 'Certain & Uncertain'. Whilst a risk is being documented, the editor can indicate whether he or she is certain or uncertain about the characteristics. If certain is selected, the only thing left is to fill out the size of the monetary and planning impact, positioned in the succeeding columns.

5.4.3 Risk assessment with unknown characteristics

If the editor selects the option uncertain whilst documenting the risk, this indicates that the characteristics are not known or to imprecise to denoted them. In more traditional forms of RM, the tool still request for a quantified estimation. This however often leads to unfounded estimations or cells that are left blank. Describing the impact's characteristics through bandwidths is inherently vague and leads to no substantial improvement. Both options lead to imprecise assumptions leading to incremental deviations in the eventual budgeting. Hence a method should be sought, capable of translating qualitative assumptions into quantitative characteristics in a dampened manner to negate warped budgeting.

In the RISMAN-method as proposed by Van Well-Stam et al. (2003) quantification of risks is only performed when additional insight is required in the feasibility of the budgeting or planning or when the risk budget requires additional substantiation. Should a quantification be performed, the focus is on the risk budgeting and planning. The latter underpins the previously made notion that every risk can be reduced to money and time, the former however goes against the notion that every risk is important and should be assessed accordingly. In the approach, the quantification is based on the combination of triangular distributions and MCS. The triangular distributions are commonly described with the minimum, most likely and maximum size of impact, indicating a likelihood distribution for these impacts. The distribution is than limited by a confidence interval to exclude rare events. Quantification is performed by adding values to the linguistic distribution descriptions through research and gathering of empirical knowledge. MCS is then used to simulate the probabilistic outcome for a given number (often 10.000) of simulations for each risk, resulting in a total risk spread for the entire project. In short this approach provides transformation from assumed probabilistic impact values into a total risk impact distribution for the entire project, though limited only to those risks in need of additional assessment. Basically this approach adheres to assessment with the renewed positioning; linguistic terms are altered into numerical values and dampening is be provided through confidence intervals. The downside is that is still requires the input of assumed characteristics, even more so than initially, thus neglecting the most essential required improvement.

Taking however the applicable elements of the approach as described by Van Well-stam et al. (2003), the approach strongly resembles the basic concepts of FL. This theory refers to fuzziness as various types of vagueness and uncertainty but particularly to the vagueness related to human linguistics and thinking. When probabilistic uncertainty cannot be determined through probability measures, fuzzy measure are introduce to mathematically handle vague terms e.g. large, average, less etcetera (Tanaka, 1997). Fuzzy set theory and the succeeding fuzzy logic (FL) have conceived by Lofti Zadeh in 1965 (Schulte, 1994) and the theory has seen prolonged application in industries such as electrical engineering, process control systems and the field of computing. In the construction market the application of FL only consists of more recent efforts. The benefit is that in each of these researches FL is applied to quantify risks. Carr and Tah (2001) proposed a formal model in which risk descriptions and their impact are defined using linguistic variables, in turn quantified through fuzzy approximation and composition to measure the influence on the project performance. Nasirzadeh et al. (2008) incorporated FL into a system dynamics model to define the imprecise and uncertain nature of risks. Through a FL based magnitude prediction system and the fuzzy Delphi method, linguistic terms are altered into crisp values or fuzzy sets through interval arithmetic. Alaneme and Igboanugo (2012) proposed a model based on FL and MCS for economic optimization in the development and management of oil fields, though not the primary subject it is akin to the construction market. FL is used to alter expert knowledge gathered through fuzzy Delphi method based on a 5-point Likert scale into a single risk level for the entire project, which is incorporated in the exploitation cost calculation. Elements of these studies are combined to create a

5.4.4 Fuzzy risk magnitude prediction system

Nasirzadeh et al. (2008) indicated Fuzzy logic as a suitable method when considering the uncertain nature of risks based on empirical knowledge and managerial subjective judgement. Altering this knowledge and judgement into numerical values requires a system based on mathematical operations. For this purpose Nasirzadeh et al. (2008) developed the '*risk magnitude prediction system'*, aiming at the determination of different risk impact magnitudes based on uncertain input factors. The resulting magnitude will serve as an input for the further simulations. The risk magnitude prediction system includes '*determination of input factors affecting the risk magnitude by fuzzy numbers, consolidation of expert inputs by fuzzy Delphi technique, and prediction of risk magnitude by a fuzzy control system*' (Nasirzadeh et al., 2008). A representation of this system is shown in Figure 5.3. Due to this research's limited time span, fuzzy Delphi techniques are omitted in this research since repeatedly approaching experts requires multiple questionnaires.

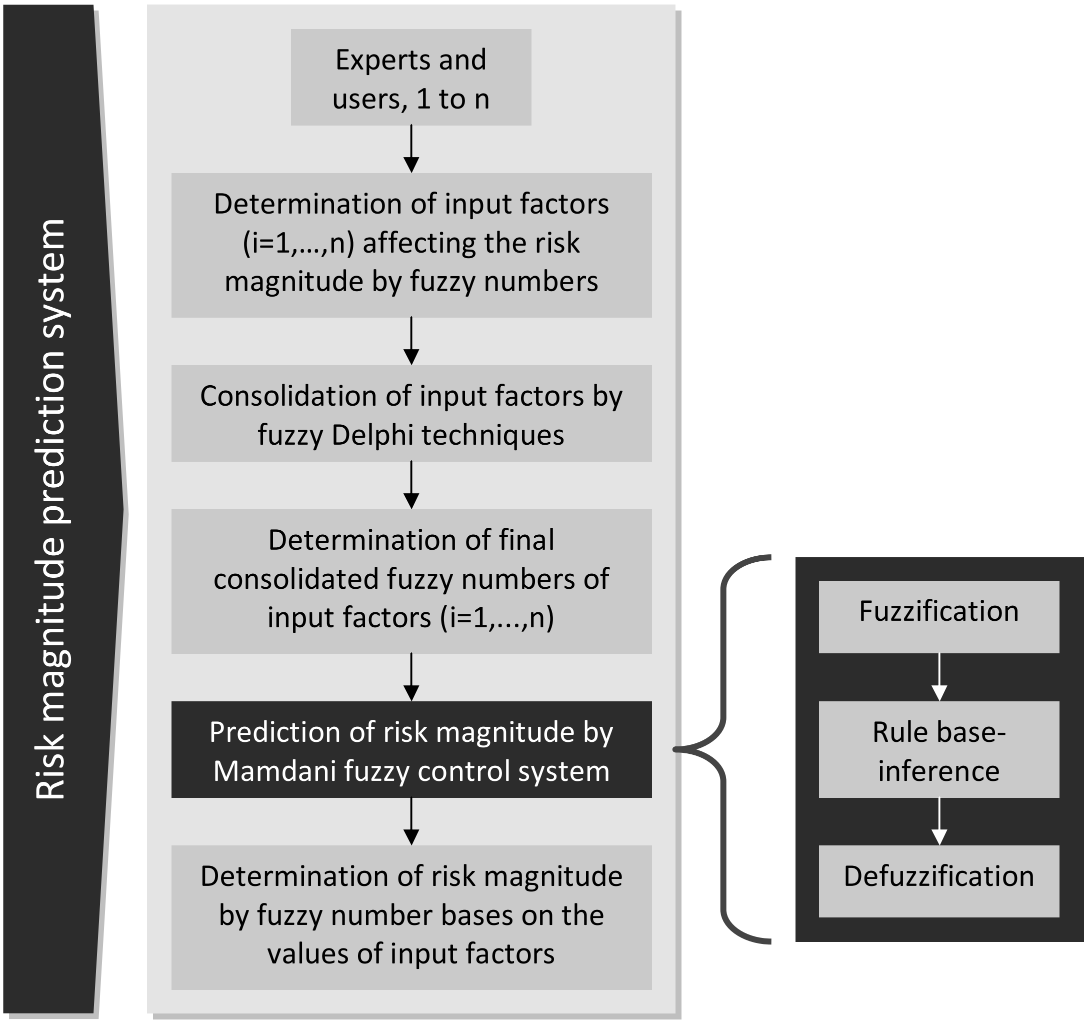

Figure 5.3 :The risk magnitude prediction system based on fuzzy numbers and logic as proposed by Nasirzadeh et al. (2008)

Determination of input factors

Every project risk is influenced by its input factors. Due to the unique nature of each project and thereby its risks, it was decided to limit the input factors to the generic GOTIKV-factors. From these factors, money and time can be omitted considering assessment of their characteristics are the aim of this process. Information is omitted as well since the gathered information is stored in this entire process of documentation, naturally this information should be of high quality otherwise the RA should be conducted more thoroughly; it is the managers task to oversee and ensure this quality. This leaves the input factors quality, environment and safety. Quality explains the state of the object or service upon which the risk expresses its influence; in case of an opportunity this influence will be beneficial whereas a threat will degrade the quality. Environment refers to the level of awareness or hindrance exposed towards the project's (direct) environment. Safety points to the extent in which (construction)workers and bystanders are placed in a hazardous situation that might lead to injuries, or are carefully positioned to negate the hazards. Due to the imprecise and uncertain nature of these input factors, their characteristics are not known with certainty. Combining this with a general lack of data for probabilistic (direct) quantification, indicates the need for implementing FL in order of '*determining the value of the input factors based on* *the experience and subjective judgment of experts involved in the project*' (Nasirzadeh et al., 2008).

Implementing first requires the fuzzification of these input factor, transforming the characteristics into linguistic descriptions. Through the linguistic descriptions the factors can be measured using the dimensionless scalar value 1,0. This allows mathematical operations between factors with different dimension is a uniform manner. The entire reach of every factor is divided into overlapping linguistic descriptions. Expert knowledge is added to these descriptions to create membership functions; based on scalar input the membership function defines to what extent the input relates to the linguistic terms (Schulte, 1993). The same approach is applied on the output factors money and time, but instead of a scalar value the impact is defined as a percentage of the overall project cost and planning; calculations should be performed relative to the project size, bandwidths are inadequate.

Fuzzification

First the input factors quality, environment and safety are transformed into linguistic descriptions. For this transformation the Likert 5-point attitudinal scale was applied, providing each factor with the scales 'limited, small, average, large and major' (Alaneme and Igboanugo, 2012). These scales describe the <u>measurement of impact for each risk on that specific factor</u>; when there is no impact regarding that factor the scale is 0 and in case of the maximum impact the scale is 1,0. The linguistic scale terms are divided amongst this scale based on their distribution, presented in the form of a triangular distribution. If linked to the linguistic definitions, this distribution becomes a triangular fuzzy number (TFN). In a TFN the experts believe the linguistic term to holds a 'most likely' value, placed between a minimum and maximum boundary. likelihood is added to these values, creating the triangular probability distribution; likelihood is also defined through a scalar value with 1 being the highest likelihood, allowing the translation to a percentage value ranging from 0 to 100%. Figure 5.4 is a visualisation of the TFN A, composed as (Nasirzadeh et al. 2008):

$$A_i = (a^i, b^i, c^i) \tag{1}$$

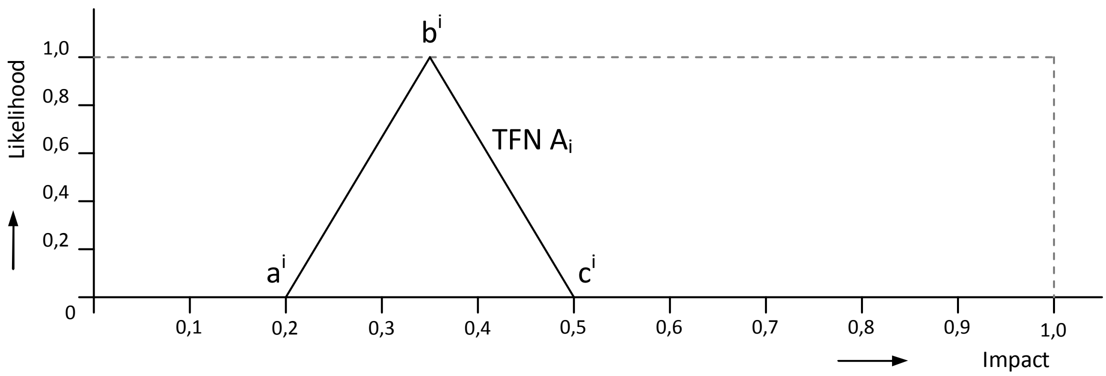

Figure 5.4: visualization of the TFN A and its distribution based on the experts values.

Where A=TFN; a,b and c=minimum, most likely and maximum value respectively; and i=ith TFN for each factor (i=1,2,3,4,5). If however an expert is certain regarding the value of the scale of impact for that factor, the value is described not as a fuzzy number but as a crisp value; the selection between certain/uncertain as incorporated in the tool foresees in the distinction between a crisp and a fuzzy number.

Questionnaire

Experts were asked to define their estimation regarding the values of each TFN in the input factors, based on his or her experience. Gathering these expert estimations is done via a questionnaire in which the experts are asked to indicate the spread, minimum and maximum value, for each linguistic definition, such that the all spreads combined fully cover the scalar scale of impact. A mixed group of 20 experts on different position were asked to give their estimation regarding these spreads by means of a questionnaire (Appendix C). In the given time span, eight expert questionnaires returned, shown in Table 5.2. The outcomes of which have been compiled and assessed to obtain estimated boundaries for each TFN.

Table 5.2:Total of eight responses on the first section of the questionnaire stating the scale of impact, all darkened cells are those that have been omitted due to deviating figures, probably due to misinterpretations

Impact size 'Money"

	A	B	C	D	E	F	G	H
Limited	0-0,25	0-0,2	0-2,0	0-0,05	0,0-0,1	0,0-0,01	0,0-5,0	0,0-0,5
Small	0,25-1,0	0,2-1,0	2,0-4,0	0,05-0,1	0,11-0,20	0,1-0,4	5,0-20,0	0,5-1,0
Average	1,5-2,5	1,0-1,5	4,0-8,0	0,1-0,2	0,21-0,50	0,4-0,6	20,0-50,0	1,0-5,0
Large	2,5-5,5	1,5-3,0	8,0-25,0	0,2-0,35	0,51-0,85	0,6-0,9	50,0-80,0	5,0-10,-
Major	5,5-10,0	3,0-10,0	25,0-100	0,35-1,0	0,85-1,0	0,9-1,0	80,0-100	10,0-100

Impact size 'Quality"

	A	B	C	D	E	F	G	H
Limited	0,0-0,15	0,0-0,1	0,0-0,05	0,0-0,05	0,0-0,25	0,0-0,1	0,0-0,1	0,0-0,02
Small	0,15-0,35	0,1-0,4	0,05-0,15	0,05-0,1	0,26-0,50	0,1-0,4	0,1-0,3	0,02-0,05
Average	0,35-0,65	0,4-0,6	0,15-0,4	0,1-0,2	0,51-0,89	0,4-0,6	0,3-0,6	0,05-0,10
Large	0,65-0,85	0,6-0,9	0,4-0,6	0,2-0,35	0,9-0,94	0,6-0,9	0,6-0,8	0,10-0,25
Major	0,85-1,0	0,9-1,0	0,6-1,0	0,35-1,0	0,95-1,0	0,9-1,0	0,8-1,0	0,25-1,0

Impact size 'Environment"

	A	B	C	D	E	F	G	H
Limited	0,0-0,15	0,0-0,1	0,0-0,2	0,0-0,05	0,0-	0,0-0,1	0,0-0,1	0,0-0,05
Small	0,15-0,35	0,1-0,4	0,2-0,4	0,05-0,1	-0,49	0,1-0,4	0,1-0,3	0,05-0,15
Average	0,35-0,65	0,4-0,6	0,4-0,6	0,1-0,2	0,5-1,0	0,4-0,6	0,3-0,6	0,15-0,25
Large	0,65-0,85	0,6-0,9	0,6-0,8	0,2-0,35	-	0,6-0,9	0,6-0,8	0,25-0,50
Major	0,85-1,0	0,9-1,0	0,8-1,0	0,35-1,0	-	0,9-1,0	0,8-1,0	0,50-1,0

Impact size 'Safety"

	A	B	C	D	E	F	G	H
Limited	0,0-0,15	0,0-0,1	0,0-0,2	0,0-0,05	0,0-0,49	0,0-0,1	0,0-0,1	0,0-0,02
Small	0,15-0,35	0,1-0,4	0,2-0,4	0,05-0,1	0,50-0,79	0,1-0,4	0,1-0,3	0,02-0,05
Average	0,35-0,65	0,4-0,6	0,4-0,55	0,1-0,2	0,80-0,89	0,4-0,6	0,3-0,6	0,05-0,10
Large	0,65-0,85	0,6-0,9	0,55-0,7	0,2-0,35	0,90-0,94	0,6-0,9	0,6-0,8	0,10-0,25
Major	0,85-1,0	0,9-1,0	0,7-1,0	0,35-1,0	0,95-1,0	0,9-1,0	0,8-1,0	0,25-1,0

Consolidation with fuzzy Delphi techniques is performed by both Alaneme and Igboanugo (2012) and Nasirzadeh et al (2008) to obtain a single, averaged TFN with the estimation of each expert within stated deviation boundaries. As stated previously, due to the limited time span this step is omitted from the research, though it is recommendable for future developments in order of achieving sufficient calibration. Instead, the outcomes of the questionnaire are compiled, assessed for their applicability and between the applicable outcomes (all others are neglected) the values for the minimum and maximum spread boundaries are averaged. These average values for the boundaries are shown in Table 5.3, resulting in the expected spread for every TFN in each factor.

Table 5.3: Average estimated values for the boundaries of every TFN in each factor

	Input factors			Output factors	
	Quality	Environment	Safety	Money (%)	Time (%)
Limited	0,0 – 0,10	0,0 – 0,15	0,0 – 0,20	0,0 – 1,0	0,0 – 1,0
Small	0,10 – 0,35	0,15 – 0,40	0,20 – 0,45	1,0 – 2,0	1,0 – 2,0
Average	0,35 – 0,60	0,40 – 0,60	0,45 – 0,65	2,0 – 4,5	2,0 – 4,5
Large	0,60 – 0,85	0,60 – 0,85	0,65 – 0,85	4,5 – 6,5	4,5 – 6,5
Major	0,85 – 1,0	0,85 – 1,0	0,85 – 1,0	6,5 – 10,0	6,5 – 10,0

Estimating these spreads was done in a single question for each factor, resulting in spread with no overlap as a direct consequence. Without the overlap between each TFN, it would mean each factor can only be described by a single linguistic description and the subsequent TFN, at a time. Such a discrete build-up of the spreads would negate the concept of fuzzy logic, hence it was assumed that these spreads are the values for each TFN at a likelihood level of 0,5 (or 50%). Also the TFN were assumed without skewness, resulting in isosceles triangular functions. All combined led to a state in which each TFN can be described through the following basic function:

$$y(x) = (ax + b) + (cx + d) \mid x \in x_{min}, x_{max} \quad (2)$$

In which:

$$a = \frac{1}{W_l} = \frac{1}{(x_{mean} - x_{min})} \mid x \in x_{min}, x_{mean} \ ; \quad (3)$$

$$b = -x_{min} * a = \frac{-x_{min}}{(x_{mean} - x_{min})} \mid x \in x_{min}, x_{mean} \ ; \quad (4)$$

$$c = \frac{-1}{W_r} = \frac{-1}{(x_{max} - x_{mean})} \mid x \in x_{mean}, x_{max} \ ; \quad (5)$$

$$d = x_{max} * |c| = \frac{x_{max}}{(x_{max} - x_{mean})} \mid x \in x_{mean}, x_{max} \quad (6)$$

Where x_{min}, x_{mean} and x_{max} are the minimum, mean and maximum values for the TFN at y(x)=0; a and c describe the slope of both sides; c and d describe the point where the function cuts the y-axis for y(X)=0; W_l and W_r are the distance are the Δx from min to mean and mean to max respectively. The average estimated values for the boundaries can now be translated into the x_{min}, x_{mean} and x_{max} in order of defining the function for the each TFN. This is done using the mathematical translations:

$$x_{mean} = \frac{x_{\min 0,5} + x_{\max 0,5}}{2} \ ; \quad (7)$$

$$x_{min} = x_{\min 0,5} - W_{l\ 0,5} = x_{\min 0,5} - \left(x_{mean} - x_{\min 0,5}\right) \quad (8)$$

$$x_{max} = x_{\max 0,5} + W_{r\ 0,5} = x_{\max 0,5} + \left(x_{\max 0,5} - x_{mean}\right) \quad (9)$$

Where $x_{min\ 0,5}$ and $x_{max\ 0,5}$ are the estimated averages for the TFN at y(x)=0,5; and x_{mean} is the most likely value for the particular TFN. Placing the experts' estimations in these latter functions gives the input for the former set of functions, thereby providing the function for a specific TFN. Table 5.4 Shows the outcome of these computations for the input factor quality. Limited and major deviate from the other TFN, due to the notion that they are only a partial triangle, limited by the scalar boundaries; 0,0 is the left boundary for the limited function and 1,0 is the right boundary for the major function, both set at x_{mean}. For the other TFN's in each factor the same computing applies, the functions of these factors are shown in Appendix D.

Table 5.4: The functions for the TFN of each linguistic variable for the input factor Quality

	x_{min}	x_{mean}	x_{max}	Function TFN
limited	n/a	0,0	0,2	$y(x) = -5x + 1 \mid x \in [0{,}0; 0{,}2)$
Small	-0,025	0,225	0,475	$y(x) = 4x + 0.1 \mid x \in (0{,}0; 0{,}225]$ $y(x) = -4x + 1{,}9 \mid x \in (0{,}225; 0{,}475]$
Average	0,225	0,475	0,725	$y(x) = 4x - 0{,}9 \mid x \in (0{,}225; 0{,}475]$ $y(x) = -4x + 2{,}9 \mid x \in (0{,}475; 0{,}725]$
Large	0,475	0,725	0,975	$y(x) = 4x - 1{,}9 \mid x \in (0{,}475; 0{,}725]$ $y(x) = -4x + 3{,}9 \mid x \in (0{,}725; 0{,}975]$
Major	0,725[6]	1,0	n/a	$y(x) = \frac{x}{0{,}275} - \frac{0{,}725}{0{,}275} \mid x \in (0{,}725; 1{,}0]$

These so-called membership functions can be visualized through graphs, for quality this is done in Figure 5.5. Such a visualization allows for a simple overview of each TFN and the relationships between them due to overlap. It also depicts the defined boundaries such that x ∈ (0,0;1,0) and y ∈ (0,0;1,0)

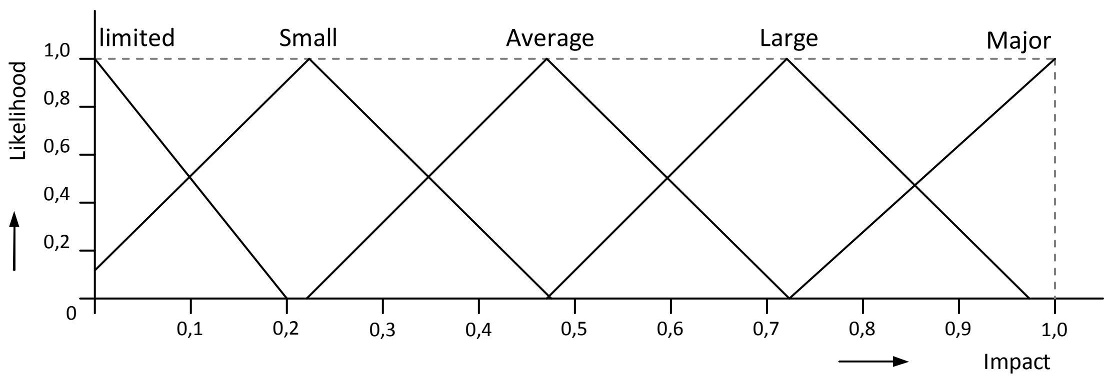

Figure 5.5: Visualization of the membership functions of the TFN's in the factor Quality

[6] Although the translation shows x_{min}=0,7; 0,725 is chosen for the continuation between the TFN's

Rule base-inference

According to Schulte (1994) inference is used to explain the behaviour of the system in which a given condition leads to an inference, commonly described using logical if-then rules. Nasirzadeh et al. (2008) states that '*the rules connect the input values with the output values and are based on the fuzzy state description that is obtained by the definition of the linguistic descriptions*'; e.g. if input TFN A = y for a given x, then the output TFN U stated with y x ∈ (0,0;y(x_A)]. This approach in which the output TFN is limited with the input factor's degree of fulfilment is called the minimum-method, also known as the MAX-MIN-inference (Schulte, 1994). This concept of inference between TFN's is shown in Figure 5.6.

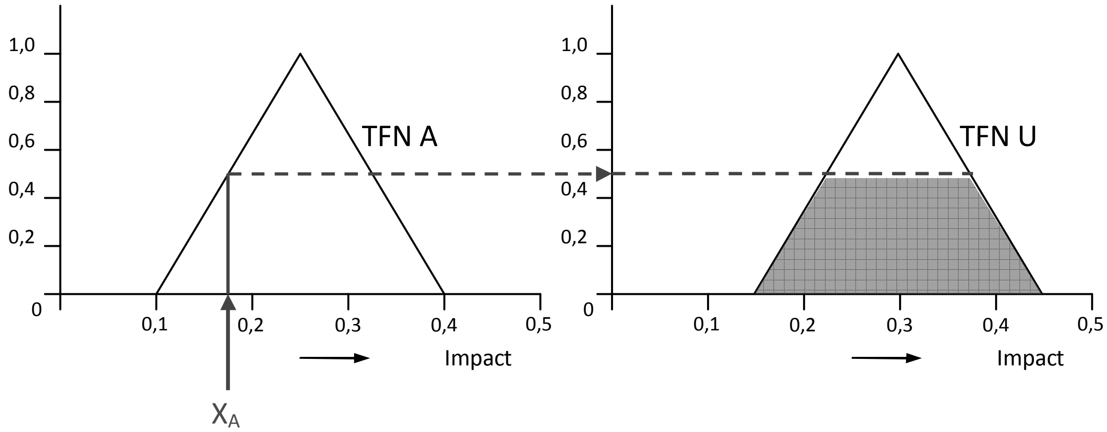

Figure 5.6 :Concept of rule base-inference between the input factor's TFN and the output factor's TFN using the MAX-MIN-inference; the red area in TFN U is the area limited with the degree of fulfilment $y_A(x_A)$.

Creating the inference's it-then rules requires the degree in which linguistic descriptions of the input TFN's relate to the output factor's TFN. Besides the input values, the experts were asked to estimate these degrees of inference during the latter half of the questionnaire. For this purpose the experts were requested to estimate the impact in terms of money for every input factor's linguistic descriptions in percentages relative to the total building cost; no direct relation was asked between the linguistic terms purposefully, because linking those might lead to a predefined boundary affecting the estimation. These percentages are shown in Table 5.5. Calculating the average values of this inference should also be based on the Fuzzy Delphi techniques, but for obvious reasons that step has also been omitted at this point in the research. Obtaining the average values is done by first omitting each estimation that vastly deviates due to misinterpretation and then summing all remaining percentages. From this total values the average value is distilled.

The estimated percentages are assessed alongside the spread of each TFN of the output factors, identifying to which membership functions the estimation belongs. This resulted in the rule base/inference between the TFN´s of the input and output factors as shown in Table 5.6. The Spread of the output factors is shown on the top side of the table, respective to each linguistic description. The inference is created by assessing in which spread and adhering linguistic description the expert value of the input factor resides.

Table 5.5: Total of eight responses on the second part of the questionnaire referring to the rule base-inference between the impact and output factors, spreads have been defined between 0% and 10% of the total project cost/planning, all darkened responses are omitted due to deviations most likely due to misinterpretations

Impact "Money"

	A	B	C	D	E	F	G	H	Average
	Quality								
Limited	0,05	0,05%	0-1%	< 1%	0,02	5	0%	0,05%	**0,04**
Small	0,25	0,10%	1-4%	< 3%	0,05	20	0%	0,10%	**0,13**
Average	0,75	0,20%	4-8%	<5%	0,1	50	1%	0,40%	**0,49**
Large	1,5	0,50%	8-40%	<8%	0,15	75	2%	0,50%	**0,93**
Major	2	1%	40-60%	>8%	0,2	95	3%	1,50%	**1,54**
	Environment								
Limited	0,2	25%	0-1%	<1%	0,01	5	0%	0,10%	**0,14**
Small	0,75	0,50%	1-2%	<3%	0,05	20	0%	0,30%	**0,40**
Average	2	0,10%	2-6%	<5%	0,1	50	1%	0,50%	**0,90**
Large	5	0,25%	6-10%	<8%	0,12	75	2%	1%	**2,03**
Major	12,5	0,50%	10-30%	>8%	0,15	95	3%	10%	**6,41**
	Safety								
Limited	0,05	25%	0	<1%	0,01	5	0%	0%	**0,02**
Small	0,15	0,50%	0-1%	<3%	0,02	20	0%	0,05%	**0,06**
Average	0,35	0,10%	1-2%	<5%	0,03	50	1%	0,10%	**0,37**
Large	0,85	0,25%	2-5%	<8%	0,05	75	2%	0,20%	**0,78**
Major	2	0,50%	5-10%	>8%	0,08	95	3%	2%	**1,77**

Impact "Time"

	A	B	C	D	E	F	G	H	Average
	Quality								
Limited	1	0,50%	0	<1%	0,03	5	0%	1%	**0,13**
Small	2,5	1%	2-4%	<3%	0,08	20	1%	10%	**0,52**
Average	5	2%	4-5%	<5%	0,1	50	2%	20%	**1,37**
Large	10	3%	5-6%	<8%	0,15	75	2%	35%	**1,72**
Major	20	4%	6-8%	>8%	0,18	95	3%	50%	**2,39**
	Environment								
Limited	1	0,50%	0-2%	<1%	0,01	5	1%	0%	**0,50**
Small	2	1%	2-4%	<3%	0,02	25	1%	1%	**0,67**
Average	4	2%	4-8%	<5%	0,03	50	2%	10%	**1,34**
Large	8	3%	8-14%	<8%	0,04	75	2%	25%	**1,68**
Major	16	4%	14-30%	>8%	0,05	95	3%	50%	**2,35**
	Safety								
Limited	1	0,50%	0	<1%	0,01	5	0%	0%	**0,17**
Small	3	1%	0-2%	<3%	0,02	25	0%	1%	**0,34**
Average	7	2%	2-4%	<5%	0,05	50	0%	2%	**0,68**
Large	15	3%	4-8%	<8%	0,1	75	1%	5%	**1,37**
Major	31	4%	8-12%	>8%	0,15	95	2%	10%	**2,05**

Table 5.6: Estimated rule base-inference between the input and output factors per linguistic description

			Money					Time				
	Input factor TFN	Expert value (%)	Limited 0,0 – 2,0 %	Small 0,5 – 2,5 %	Average 0,75 – 5,75 %	Large 3,5 – 7,5 %	Major 7,5 – 10,0 %	Limited 0,0 – 2,0 %	Small 0,5 – 2,5 %	Average 0,75 – 5,75 %	Large 3,5 – 7,5 %	Major 7,5 – 10,0 %
Quality	Limited	0,04	X					X				
	Small	0,13	X					X	X			
	Average	0,49	X					X	X	X		
	Large	0,93	X	X	X			X	X	X		
	Major	1,54	X	X	X					X		
Environment	Limited	0,14	X					X	X			
	Small	0,40	X					X	X			
	Average	0,90	X	X	X			X	X	X		
	Large	2,03		X	X			X	X	X		
	Major	6,41				X	X		X	X		
Safety	Limited	0,02	X					X				
	Small	0,06	X					X				
	Average	0,37	X					X	X			
	Large	0,78	X	X	X			X	X	X		
	Major	1,77	X	X	X				X	X		

Table 5.6 states that when a risk manifests itself and the impact on quality will be ´major´, the degree of fulfilment for the financial impact of that factor is estimated at 1,54%. This value is a member of the output factor ´money´ in the descriptions ´limited´ (0,0;2;0), ‘small’ (0,5;2,5) and ‘average’ (0,75;5,75); if stated as a logical function:

If ‘quality’=’major’, then ‘money’=(‘limited’; ’small’; ’average’)

These rules can be stated using the inferences, providing the basis for the final step in the fuzzy control system. For ‘time’, the same TFN’s were assumed as for ‘money’, creating identical membership functions; the rule base-inference however is done separately, thus providing different insights for the planning.

Defuzzification

Schulte (1994) explains defuzzification as transforming the inference induced fuzzy value of the output factor into a crisp value. This step is required since the statement $y_{if}(x_{if})$* ‘limited’ is unusable for further computation. Through defuzzification, such a statement can defined as a crisp risk characteristic. Nasirzadeh et al. (2008) proposed the use of the ‘centre of area (COA) method’ for the defuzzification. The thought of this method is calculating the value x for the centre of gravity of the area underneath the membership functions pointed out by the rule base-inference and the degree of fulfilment of the input factor. Calculating the COA is done with:

$$x^{COA} = \frac{\int_x x * y(x)dx}{\int y(x)dx} \quad (10)$$

Where x^{COA} = the x-value of the COA, thereby the crisp value risk characteristic of that output factor; and y(x) is the membership function of the TFN in subject. Performing this calculation, the degree of fulfilment of the input factor should be taken into account. This degree has its impact on the membership function's internal boundaries, turning the function in a trapezoid as shown in Figure 5.7.

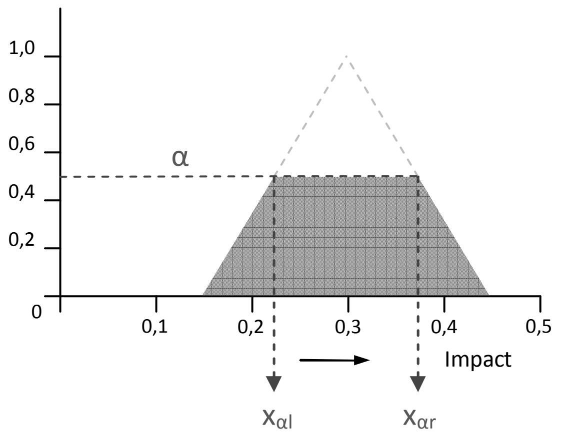

Figure 5.7: Visualisation of the effect of the input factor's degree of fulfilment on an output factor TFN

The above visualization shows the dependence of the TFN on the degree of fulfilment indicated as α, in which $\alpha = y_{if}(x_{if})$. Calculating the COA now requires a computation with three functions and the definition of the internal boundaries described by $x_{\alpha l}$ and $x_{\alpha r}$. The latter two can be done by inverting function (2):

$$x_{\alpha l} = \frac{y-b}{a} \quad (11)$$

$$x_{\alpha r} = \frac{y-d}{c} \quad (12)$$

Table 5.7: Overview of the internal boundary functions for the output factors' TFN's

	TFN membership functions	Internal boundary functions
Limited	$y(x) = (-x/2) + 1 \mid x \in [0,0; 2,0)$	$x_{\alpha r} = -2 * y + 2 \mid y = \alpha$
Small	$y(x) = x - 0.5 \mid x \in (0,5; 1,5]$ $y(x) = -x + 2.5 \mid x \in (1,5; 2,5]$	$x_{\alpha l} = y + 0,5 \mid y = \alpha$ $x_{\alpha r} = -y + 2,5 \mid y = \alpha$
Average	$y(x) = (x/2,5) - 0.3 \mid x \in (0,75; 3,25]$ $y(x) = (-x/2,5) + 2.3 \mid x \in (3,25; 5,75]$	$x_{\alpha l} = 2,5 * y + 0,75 \mid y = \alpha$ $x_{\alpha r} = -2,5 * y + 5,75 \mid y = \alpha$
Large	$y(x) = (x/2) - 1,75 \mid x \in (3,5; 5,5]$ $y(x) = (-x/2) + 3,75 \mid x \in (5,5; 7,5]$	$x_{\alpha l} = 2 * y + 3,5 \mid y = \alpha$ $x_{\alpha r} = -2 * y + 7,5 \mid y = \alpha$
Major	$y(x) = (x/2) - 2,25 \mid x \in (5,5; 7,5]$ $y(x) = 1 \mid x \in (7,5; 10,0]$	$x_{\alpha l} = 2 * y + 4,5 \mid y = \alpha$

Determining these internal boundaries requires the computed membership functions of either one of the output factors as shown in Appendix D; since money and time have identical membership functions, the internal boundary functions are identical as well.

By using the internal boundaries, calculated with the functions as shown in Table 5.7, the functions for the COA can be stated. As indicated before in function (10), this calculations uses integrals to determine the surface area underneath the adjusted TFN of the output factor. Calculating these integrals first requires the adjusted, trapezoid-shaped membership functions:

$$y(x) = (ax + b) + \alpha + (cx + d) \mid x \in x_{min}, x_{max}, \alpha \in x_{\alpha l}; x_{\alpha r} \tag{13}$$

In which:

$$a = \frac{1}{W_l} = \frac{1}{(x_{\alpha l} - x_{min})} \mid x \in x_{min}, x_{\alpha l} \;; \tag{14}$$

$$b = -x_{min} * a = \frac{-x_{min}}{(x_{\alpha l} - x_{min})} \mid x \in x_{min}, x_{\alpha l} \;; \tag{15}$$

$$c = \frac{-1}{W_r} = \frac{-1}{(x_{max} - x_{\alpha r})} \mid x \in x_{\alpha r}, x_{max} \;; \tag{16}$$

$$d = x_{max} * |c| = \frac{x_{max}}{(x_{max} - x_{\alpha r})} \mid x \in x_{\alpha r}, x_{max} \tag{17}$$

Which can be transformed into:

$$x^{COA} = \frac{\int_{x_{min}}^{x_{\alpha l}} x*(ax+b)dx + \int_{x_{\alpha l}}^{x_{\alpha r}} x*\alpha dx + \int_{x_{\alpha r}}^{x_{max}} x*(cx+d)dx}{\int_{x_{min}}^{x_{\alpha l}} (ax+b)dx + \int_{x_{\alpha l}}^{x_{\alpha r}} \alpha dx + \int_{x_{\alpha r}}^{x_{max}} (cx+d)dx} \tag{18}$$

Through this function the crisp value can be computed for a single output factor TFN. There are however cases where a single inference relates to multiple output factor TFN's for a single α. In that case, the adjusted membership functions are combined into a single defuzzification integral, or:

$$x^{COA} = \frac{\int_x x*y_1(x)dx}{\int y_1(x)dx} + \cdots + \frac{\int_x x*y_n(x)dx}{\int y_n(x)dx} \mid n = 1,2,3,4,5 \tag{19}$$

Where n = the total number of TFN's implied through inference, e.g. *"If 'quality'='major', then 'money'=('limited'; 'small'; 'average')"* the total number of implied TFN's n=3. But not only the output factors can encompass multiple TFN's, the same goes for the input factor TFN's. If that case should arise, the crisp value for each separate input factor TFN can be calculate through inference and defuzzification, after which the crisp values are added and divided by the total number of values thereby providing the average:

$$\bar{x}^{COA} = \sum_{i=1}^{m} (x_i^{COA})/m \tag{20}$$

Where m = the total number of input factor TFN's defined by the input value. The extend of membership, y(x), determines the α for each input factor TFN; since the x^{COA} of every defuzzification is calculated using the different α's, a weight factor is included into the overall calculation.

Fuzzy risk assessment outcome
Through this intricate prediction system, uncertain risk characteristics can be estimated based on the size of their impact. All these computations are placed on separate sheet, which are locked to ensure no, unwanted, alterations to the operators. This means the only task for the editor of a risk with uncertain characteristics, is estimating the expected impact of a risk on the factors quality, environment and safety; these values can be documented in the appointed columns in the tool and are stated in percentages. The calculations that follow are performed automatically at the moment of documentation and provide a final crisp value for the impact in percentages of the total direct construction cost (factor money) and of the total project duration (factor time). To support the estimation of the impact size, several descriptions have been made which are directly linked to the fuzzy linguistic description. Through these descriptions, the editor has a reference when making the estimation. For the input factor quality these descriptions are shown in Figure 5.8 relative to the impact size, for the other input factors the descriptions are noted in Appendix E.

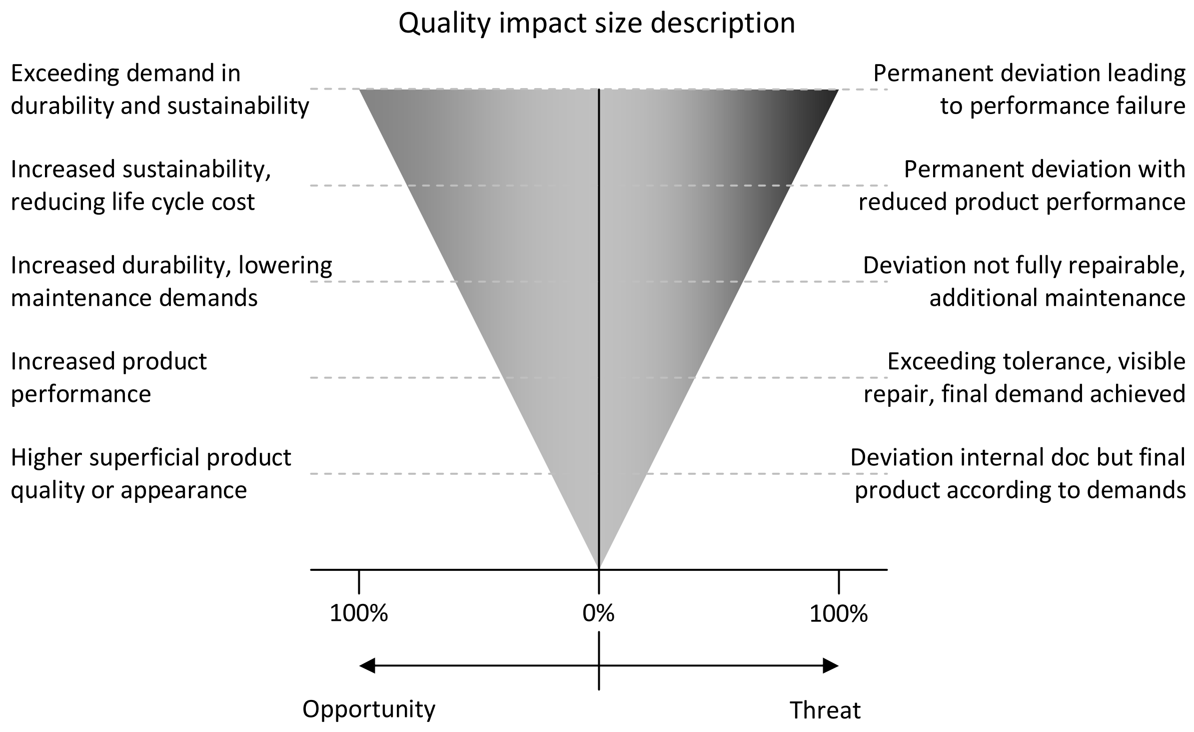

Figure 5.8: Impact size descriptions linked to the relative impact size, set on the fuzzy linguistic descriptions

5.5 Risk measures

With the risks and their characteristics identified, the next activity is defining risk measures which was explained as '*creating befitting measures capable of mitigating, remediating or replacing the identified threats and to increase and promote opportunities*'. In Chapter 4.2.2 different options regarding the measures were explained, being promotion/prevention, increase/mitigate, obtain/transfer and contingency. Further examining of these options indicates a division into '*proactive control measures*' and '*reactive response measures*'. The criterion for this division is based on whether the proposed measure is performed **before** or **after** manifestation. Of the four proposed options, only contingency is performed as a post-manifestation response by developing a measure to negate the effects together with setting aside the required resources for this measure. Hence contingency is regarded as a response measure, simultaneously denoting the other three options as control measures.

5.5.1 Control measures

As formerly stated, control measures are applied before manifestation to promote, increase or obtain opportunities and to prevent, mitigate or transfer threats. In the tool, developing control measures is regarded as a separate activity, thus placing it on a new sheet in the tool. Yet again, each risk is separately documented in a single row and the first columns summarize the risk. The following columns foresee in:

- **Control (proactive) measure**: In this field, the risk editor explains the control measure, answering questions as *´Which actions are to be deployed? What is the expected effect? On what elements does the measure apply?´* The aim is to provide a SMART description describing what is targeted specifically, what the extend of the measure will be on the impact, attainable with available resources and providing a relevant improvement to the project and feasible within a set time span;
- **Target department:** Based on the category, it is possible to place each risk and the adhering measure in the internal (or external in case a third party is brought in) department best capable at implementing the measure; e.g. a structural risk during project preparation is best placed in the hands of the engineering department. By placing the measure where the knowledge resides, the most effective and efficient measure can be developed, combined with the highest possible success likelihood;
- **Control measure owner**: Appointing ownership, means handing a single person the responsibility of ensuring that the control measure is deployed as defined. This owner is not necessarily the one performing the actions following the measure, but he or she carries the task of ensuring its deployment. This action is of main importance for the project management; if a measure is not performed correctly or not performed before the stated deadline, they can direct their comments to the owner of the control measure thus creating enhanced process control;
- **Control measure cost**: Although a suitable preventive control measure negates the increased risk budgeting in case of threat, there might be cost involved with the actions of the measure itself. Documenting these costs increases traceability of made expenses during and after the project;
- **Control measure success likelihood**: Even though the developed control measure is placed in the most suitable department and defined as SMART as possible, it still does not ensure a successful influence on the risk. The degree in which the editor is certain of successful implementation of the developed measure, is indicated with the control measure success likelihood. For purposes of simplicity, this likelihood is been split into three different categories, being 'likely, doubtful and unlikely'. The editor can select either one of these categories, without having to contemplate about the precise likelihood. In a later stage, the management or board of directors (hencefort indicated by descision making unit, or DMU) will decide upon the actual value of

these success likelihood categories (SLC's), effectively separating project development aspects and entrepreneurial aspects. In the tool the selection is provided through dropdown menus.

5.5.2 Response measures

Equal to the control measures, the response measures are placed on a new sheet to support the separation of the two notions. Nevertheless, the sheets show similarities; the **risk summary** is present and for each response measure the **response (reactive) measure description**, **target department** and **owner** must be documented. The control measure cost have been omitted since they are either incorporated in the threat cost at manifestation or not applicable when an opportunity is not seized. On the other hand the summary has been extended with the **success likelihood value** of the control measure and the **expected risk budgeting and planning impact**; the latter two have been defined with either the known risk characteristics or using the fuzzy risk magnitude prediction system. Combining the success likelihood and these characteristics expressed in money and time, allows for a prioritization; those risks holding the lowest success likelihood together with relatively high characteristic values, could be deemed of high priority for further assessment or measure development. Providing this prioritization is done using the inbuilt filter function of excel, allowing for a multiple criteria sorting of the documented information.

5.6 RA summary

The amount of information gathered and documented during the RA process can lead to an extensive document which in turn may be inconvenient for internal and external communications. In order of limiting the information opted for conveying, the information is summarized into statistical overviews. These overviews stored in the RM summary, encompassing both a statistical and a budgeting overview.

5.6.1 Risk management summary

When communicating regarding the RA, the core information is on the degree of risk residing with a project, meaning the total number of opportunities, optimization and threats, their subsequent spread along the discipline based and measure SLC and the budgeting involved with every SLC. Summarizing these aspects is done via table in which the rows represent the SLC's and the rows each discipline based category. Each identified risk is assessed with these two aspects as criteria and modelled using logical if-then functions. Below every column, the total number of risks in each discipline category is summed, giving insight in the total number of risks. At the end of each row, the total risk budgeting per success likelihood category is displayed, e.g. if for the opportunities of which the SLC is 'Likely' and the total opportunity budgeting €10.000,-, this means it is likely (actual value is determined by the DMU, then explained as 'the probability of success in %') that a reduction of €10.000,- is achieved.

The found numbers are visualized through two diagrams. The first is a stacked bar graph, stating the number of opportunities, optimizations or threats per SLC, divided amongst the discipline categories; three stacked bars display the total number, whilst each bar has its own subdivision per discipline category. The benefit of this graph is to see the risk spread based on the expected successfulness of their response measure, e.g. if the '*threat measure success spread*' depicts ten threats in '*likely*', two in '*doubtful*' and four in '*unlikely*', the number of adequate measures is high but additional attention might be required for the four in '*unlikely*'. The second diagram is a pie-chart, showing the expected influence on the budgeting per SLC, also divided between opportunities, optimizations and threats. This chart will display which SLC holds the largest share of the budgeting per risk nature, e.g. if the total threat budgeting is €50.000,- divided as '*likely*' is €10.000,-, '*doubtful*' is €5.000,- and '*Unlikely*' is €35.000,-, the biggest budgeting improvement can be obtained by increasing the success likelihood of the risks in the 'u*nlikely*' category.

Although this summarization provides no insight in the actual risk, control measure and response measure descriptions, it provides clear overview of the spread of the risks, their characteristics and successfulness of the developed measures. It singles out the strong points and the areas of attention within the project regarding RM. Overall, the main aims of RA is to define suitable measures and adequate budgeting. The former are provided through the developed measures, the latter can be computed using the expected risk budgeting and planning impacts. The aim is to provide the project management with a single-page financial summary stating the required risk budget which is presented to the board directors. The latter are to judge the budgeting by comparing it with the expected project margins, e.g. if the maximum budgeting is fully covered by the margins whilst leaving residual margin as well, the project can be deemed a suitable investment.

However, developing this budgeting is subject to uncertainty stemming from the success likelihood and the level of risk acceptance. Due to this uncertainty, the budgeting is presented as a spread, based on scenarios. Calculating this spread requires several, entrepreneurial steps, the first one being the estimation of the values for the SLC's; the is asked to estimate the expected level of success for every category in percentages. Combining these values with the expected risk budgeting and planning impacts, the total success likelihood adjusted risk budgeting and planning impact can be calculated. Alaneme and Igboanugo (2012) proposed the use of MCS for economic optimizations. In this simulation, random numbers were picked for the risk manifestation, resulting in a single project risk value. This single value was then used to calculate the projects Net Present Value (NPV); since this simulation was performed 10.000 times, the result was a normal spread (assumed) of the projects expected NPV. Identical to this approach, the aim of this summary is to obtain an expected risk budgeting with a normal spread. For this purpose MCS was adopted, altered and applied.

Monte Carlo Simulation

For this research, the step of calculating a single risk value has been omitted and the MCS is applied to calculate the expected risk budgeting spread directly. For this calculation, the estimated values for the SLC and the expected risk budgeting and planning impact are required. Based on these inputs, the simulations are made using logical '*If-then*' functions. These functions are inhibited by using the nature of the risk as criteria. Optimization as a criteria is extended with the status; if an optimization is to be applied it can be seen as a opportunity, when applied it is perceived as a threat. These logical functions are explain in Table 5.8.

Table 5.8: Logical if-then functions under different criteria

Nature & status	If	Then	Else
Opportunity & Optimization - To be applied	r<SLC	Exp. budgeting (-)	0
Threat & Optimization - Applied	(100-r)<SLC	Exp. budgeting (+)	0

Where r is a random number with r ∈ (0;100) in a continuous manner; and **expected budgeting is explained relative to the total risk budget**; an opportunity will reduce the need amount of financial resources, thus receiving a negative operator, and a threat will increase the total risk budget, thus receiving a positive operator. This notion is extremely important! Risk budgeting is perceived from different standpoints; Opportunities raise the customer value thereby the return for the organisation, hence opportunities are perceived as beneficial for the return with the opposite for threats. Another view is the impact of opportunities and threats on the project margin, opportunities increase the margin and threats will decrease the margin, being positive and negative respectively. However both views neglect the actual comparison of the risk budgeting in respect to the margin or in that line, the project's return. To create this ability of providing a separate risk budget which can be compared to the margins, **opportunities are perceived as an entity capable of reducing the overall risk budget**, hence a negative figure. **Threats are perceived as an entity capable of increasing the risk budget**, hence a positive figure. Because more transparency increases the accuracy and management capabilities, the tool assumes the latter standpoint.

From this standpoint a single simulation would state an opportunity and the random likelihood value r ∈ SLC then the total risk budget will be reduced with the expected budgeting, if r ∉ SLC then there will be no effect on the budget; this goes for a '*to be applied optimization*' as well. If the simulation would state a threat and the random likelihood value (100-r) ∈ SLC then the expected budgeting will added to the total risk budget, if (100-r) ∉ SLC then there will be no effect on the budget; this also goes for an '*applied optimization'*. In case of the latter simulation the r is deducted from a total probability of 100% since r indicates the success likelihood of the control measure; if the control measure were to be successful, the threat will not manifest itself, e.g. if the SLC is 'likely'=90% only in 100-90=10% of the case will that threat lead to a manifestation thereby an addition to the total risk budget.

The principle of MCS is based on performing a single simulation multiple times, commonly with 1.000 or 10.000 repetitions. In this tool one budget or planning simulation is comprised of single simulation for each risk using the functions as explained in Table 5.8. All outcomes of the separate risks are added into one simulated risk budget. This simulation is repeated 5000 times[7], resulting in an equal number of simulated risk budgets. These budgets combined form the spread of possible budget sizes and is assumed to be a normal spread. Next, the mean, minimum, maximum and standard deviation can be determined, giving the characteristics of the total risk budgeting, performed separately for both 'money' and 'time'. These simulations have been placed on separate sheets as with the FL sheets, and use the documented information from sheets 1 through 4 as input.

[7] Deliberately chose a more precise spread without impairing the tools operating speed

Total project risk budgeting

Measurements of both budgeting and planning impacts are provided in a spread based on scenarios. For this purpose, a five point scenario scale was devised consistent of the '*best-best, best, average, worst and worst-worst case*' scenarios. Table 5.9 shows the definitions of the different scenarios. These scenarios are calculated for the budgeting and planning impact separately and visualised along a spread-bar as shown in Figure 5.9.

Table 5.9: five impact scenarios and the definition for each of these scenarios

Scenario	Definition
Best-Best	All opportunities' SLC=100%, all threats' SLC=1000%
Best	MCS minimum value
Average	MCS mean value
Worst	MCS maximum value
Worst-worst	All opportunities' SLC=0%, all threats' SLC=0%

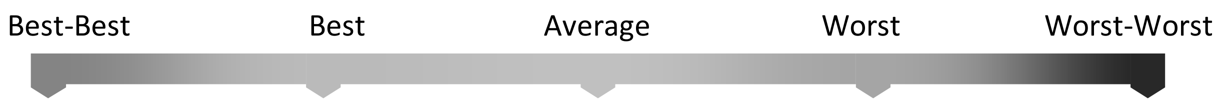

Figure 5.9: Scenario spread-bar, visualisation graph in which the different scenario values are depicted

project's objective functions. With these spreads in place, the DMU is asked to take the second entrepreneurial decision: '*How much risk is acceptable for this project?*' This level of risk acceptance indicates to what degree the actual risk budget realisation is certain to reside within the scenario spread. This degree is known as the confidence interval, or the degree in which one is certain that the outcome will reside within the interval. For this, the DMU is requested to indicate the degree they are willing to accept relative to the total budget in percentages, explained as P^{-1} | P^{-1}=(1, 2, 5, 10, 20, 30, 40, 50, 100); e.g. if the DMU decides that the project van handle 5% risk (or uncertainty), it is 95% certain the realised risk budget will be within the risk budget's minimum and maximum value. Upon selection the accepted risk value, the confidence interval $(\bar{X}_{min}, \bar{X}_{max})$ can be calculated using:

$$\bar{X}_{min} = \bar{X} - z\frac{\sigma}{\sqrt{n}} \quad (21)$$

$$\bar{X}_{max} = \bar{X} + z\frac{\sigma}{\sqrt{n}} \quad (22)$$

Where $(\bar{X}_{min}, \bar{X}_{max})$ are the minimum and maximum boundaries of the confidence interval respectively; $\bar{X}$ is the calculated mean from the MCS; z is the cumulative probability adhering to the confidence level P=(100-P^{-1}), derived from the statistic t-table (Nieuwenhuis, 2009); σ is the standard deviation MCS; and n is the number of simulations performed in the MCS. Using these functions the confidence interval is calculated for the risk budgeting and the planning impact separately. The calculate risk budgeting spread already states the desired spread of required financial resources, the planning impact however is still stated in days and needs to be altered to financial values in order of calculating the total project risk budgeting. For this purpose, the calculated $\bar{X}_{,min}$, $\bar{X}_{max}$ for the planning impact in days, are multiplied with the fine in €/day for the number if days the realisation exceeds the planning, this is called a client discount; in case bonus is given for a premature delivery, the number of days deceeding the planning are multiplied with the bonus in €/day. These figures are than added to the calculated $\overline{\mathrm{X}},_{\min}$, $\overline{\mathrm{X}}_{\max}$ risk budgeting interval, resulting in the risk-acceptance adjusted total project risk budgeting.

With the outcome of the entire assessment, the DMU can compare the minimum, average (or expected) and maximum risk-acceptance adjusted total project planning budget with the project's margins to determine the spread of the risk adjusted net return on the project. This final value indicates whether a project is deemed profitable or can be seen as a liability for the organizations turnover rate.

5.7 Project management plan

The PMP is the second outcome of the RA process (RAP) and serves as a managerial tool by stating all the developed control and response measures. Those measures are defined into actions to which owners are designated along with a stated set of measurable performance criteria. This document forms the input for the RMP and gives the manager in charge of the actual project phase the ability to steer and observe the progress of the implementation of the response measures. Altering the descriptive information into clear, SMART actions, results in a much more effective implementation of the RM in the entire process of project development. The PMP also provides status updates on predefined intervals, making the process of RM more manageable.

5.8 Conclusion

Developing a tool based on the proposed framework, required the selection of several methods linked to the stepwise procedure. The outcome is an excel based tool in which each step is represented with at least a single sheet, resulting in four input sheets, two result sheets and several calculation sheets. The input sheets are used for documenting the risk information and made recognizable using blue colours. All input sheets are identified with a number:

1. **Risk identification**: This sheet is used to document the basic description of each identified risk. This basic identification consists of a description, nature, category (discipline based) and status. For sakes of traceability, each risk also receives a number, tag and the editor of the risk is obliged to note his or her name. For simplicity, all fields that require an input are indicated with a light blue filling, all automatically generated fields receive a darker blue filling.
2. **Risk assessment**: The first section of this sheet consists of risk information transferred from the first sheet. The second section aims at defining the risk characteristics in terms of the factors 'money' and 'time'. Whilst defining these characteristics, the editor has to indicate whether he or she is certain regarding the values of these characteristics. In case the editor is certain, the expected impact in terms of money and planning can be documented. When however, the editor is uncertain of these values or there is no knowledge present, the impact can be estimated using FL in terms of 'money' and 'time'. The editor indicates his or her estimation regarding the impact size of the risk on the input factors 'quality, environment and safety' in terms of percentages where 0% is no impact and 100% is the maximum impact. These values are treated as input for the fuzzy risk magnitude prediction system, which alters these input factors into crisp value outputs for the

factors 'money' and 'time' in terms of percentages of the total contraction cost and total project duration respectively. Independent of the chosen certainty, the outcome will always be stated in terms of 'money' and 'time'.

3. **Control measures**: With the characteristics known, suitable control measures can be developed. These proactive measures are used to promote, increase or obtain opportunities and to prevent, mitigate or transfer threats. Again the sheet starts with a summary of the basic risk information, then the editor needs to document the control measure description, target department, control owner, control cost and the control measure success likelihood category. The latter is a category-based aspect, defining how successful the developed measure will be when implemented. To simplify the model, this aspect has been divided into the categories 'likely, doubtful and unlikely'. Actual values in percentages will substitute these linguistic descriptions later on, but defining these values is a task given to the DMU.
4. **Response measures**: In case a control measure has not been developed or is not successful, a response measure is required when a risk does manifest itself. The information documented for these reactive response measures is identical to that of the control measures, minus the control cost (these are incorporated in the expected risk budgeting and planning impact) and the SLC. Prioritization is enabled on this sheet by filtering the risks on the expected risk budgeting and planning impact, added to the risk information. Risks with a high budgeting or impact might require more urgent attention, especially if the SLC is considered 'unlikely'.

Following the input sheets are the result sheets. These sheets are identified with the colour green and labelled with letters:

A. **RMS - Statistics**: On this sheet all risks are statistically summarized based on their discipline category, SLC and budgeting. Opportunities, optimization and threats are summarized separately. The first step is the creation of a stacked bar-graph which displays the number of opportunities, optimizations or threats in each SLC, subdivided into the discipline categories. This provides an overview of the total number of entities for each specific risk nature and how likely these risk are managed during the RMP. Second is a pie-chart displaying the share of each SLC on the total budgeting for each risk nature. This allows insight in the strong points and attention areas of the entire project.
B. **RMS - Budgeting**: Eventually, all information regarding the identified risks can be altered into a expected impact spread for both 'money' and 'time'. On this single page sheet, the DMU first needs to identify the values for the SLC's, serving as input for the MCS. This MCS provides the minimum, maximum and mean expected budgeting and planning impact for the entire project, documented as scenarios. Based on this expected spread, the DMU can then determine the degree of risk acceptance. Through confidence interval calculations, this acceptance is turned into the total project risk budgeting and total planning impact. The latter is altered into values for the factor 'money' based on client discounts or contractor bonuses, finally prompting the risk-acceptance adjusted total project risk budgeting, explained as spread with a minimum, average (expected) and maximum value. This final value is compared to the project margins by the DMU to determine the net return on the project.

Making all mathematical operations work, the tool relies on several calculation sheets. Three of these sheets encompass the calculations of the FL and two others all simulations for the MCS. These sheets are all identified with the colour red and received a generic label '#'. Also, these sheets will be locked so none of the users can make alterations, accidental or intend. As an example of the final model, one could look at Appendix F or G. These show the filled out tool (partially) for the verification and validation cases. They also give an impression of what the tool looks like.

A separated outcome, not designed as a sheet, is the PMP. In this document all developed control and response measures are summarized and altered into activities with a designated owner and criteria. With this document, the manager in charge of the phase in which the project resides, obtains improved control of the process. Simultaneously this document improves the integration of the RMP in the entire process of project development by making the developed measure measurable and appointing ownership.

5.8.1 Research progression

The implementation of the proposed RMF as outline for the process gains additional support of the newly developed tool. Linking the different sheets to every process step, foresees in an adequate storage of information relevant for each RA activity. This also means the entire process revolves around the proposed framework, creating an uniform approach. The last step required to complete the approach is defining which actions need to be deployed during each of the steps in order of gathering the desired information. In the following the chapter these actions will be explained, together with an expleratory case study to display, verify and validate the functioning of the tool through an actual case.

6 Verification and validation of tool-based approach

Performing RA and RM with the framework and the supportive tool at its basis provides the basic structure for the process, but this only of partial importance when trying to increase both the efficiency and effectiveness of RM. Due to the tool all required information is documented and only the crucial information is conveyed to the DMU's; unnecessary activities are omitted, simultaneously reducing the input information. However, gathering only the required information points out the necessity of performing actions capable of providing that very information. Selecting these actions and implementing them in the process requires a person in charge of structuring these actions according to the framework and tool, thereby providing effectiveness. In this chapter both the efficiency and effectiveness will be discussed; the latter is done by stating possible actions and how the appointed responsibility should be perceived. The former is assessed through verification and validation. Verification will be provided by a simple energy management example, whereas validation is performed by taking an actual case and placing it in the model

6.1 Tool-based data collection

During the risk identification and following assessment the basic characteristics of the risks need to be collected; PMI (2000) describes risk identification as '*the iterative process of determining which risks might affect the project and documenting their characteristics with the participation of the project manager, team members, risk management team, customers, subject matter experts, end users, other project managers, stakeholders and risk management experts*'. Large involvement is needed, according to Elkington and Smallman (2002) the efficiency of the identification process can be raised by harnessing the skills and experience of others.

6.1.1 Data collection approaches

Gathering the information is achieved by studying the project from different angels in a systematic manner According to Van Well-Stam et al. (2003), achieving a complete as possible risk documentation. This ensures variation during the identification, increasing the effective range[8]. In order of conducting this gathering systematically, two approaches are commonly deployed. One possibility is commissioning a risk review conducted by a designated team. This team has to identify the risks associated with all operations and activities deployed by the organisation in relation to its objectives. Conducting the identification and assessment takes place through interviews with key staff at every level of the organization to achieve a full range coverage. The other possibility is risk self-assessment in which all levels and part of the organization are invited to review the operations and activities and add to the analysis of the risks. This process can be structured through a documentation approach with an analysis framework based on questionnaires or through facilitated workshops. In case of the latter, facilitators with appropriate skills support the staff analysing the risks. Applying this approach establishes better ownership towards the RMP by having the team members themselves conducting the identification and assessment. By appointing ownership of certain opportunities or threats, the responsibility of managing and monitoring the measures then befalls the owner. However, the owner is not necessarily the very person taking the action since sufficient authority is needed, aligned with the accountability, to ensure effective management. Because of the difference in the

[8] It is important to realize that even when the range is extended, achieving a hundred percent complete analysis is impossible due to unknown events that cannot be identified during the initial analysis.

approaches, perception of the risks within the organization could differ significantly. Hence, a combination of the two approaches is most desirable, considering they are not mutually exclusive (HM Treasury, 2004). In such a combination, the risk review mainly focuses on the organizational level, providing the risks on a strategic level. The risk self-assessment is performed at project level; Van Well-Stam et al. (2003) state that self assessment is '*structured through a documentation approach with an analysis framework based on questionnaires or through facilitated workshops*'. That the framework and documentation approach have been provided in this research is evident. The notion that the framework is based on questionnaires and workshops indicates the necessity of deploying additional actions within the framework, aiming at the data collection (gathering of information) which in turn is stored using the tool.

6.1.2 Data collection actions

Several actions can be deployed to conduct the data collection, divided amongst the two approaches. These methods are listed in Table 6.1, together with a short description of their functioning and the approach in which they fit. None of these methods are applied exclusively, but require combining to obtain a full extension of the range; ensuring access to both documented and empirical knowledge. RA and the subsequent RM are tailored to fit the project parameters. When conducting the actual identification the selection of the actions is based on the phase in which the project resides, the involved staff, the accessible documentation, project complexity and size, available resources and desired results with quality at a stated level (Van Well-Stam et al., 2003).

Table 6.1: Description of possible actions for data collection (PMI, 2000; Elkington and Smallman, 2002)

Method	Description	Approach
Documentation reviews	Studying all documents that describe the specifics of the project such as plans, (previous) project files, contracts etc	Risk review
Interviewing	Questioning (key) staff members from every level in the organisation/project regarding their perception of risks	Risk review
Checklist analysis	Studying the risk structure from its lowest level of detail and working upwards, based on historical information and knowledge	Risk review
Assumption analysis	Analysing the validity of assumptions together with their accuracy, instability, inconsistency or incompleteness; more regarded as check for earlier statements	Risk review
Expert judgement	Gathering all knowledge from experts regarding the field of RM, could be done via interviews as mentioned above	Risk review
Root cause analysis	Identifying not just the OR, but the cause as well and developing response measurements befitting the cause	Self-assessment Risk review
Brainstorming	Grouping (key) staff gathering, structuring and categorizing a comprehensive list of all OR involved in the project	Self-assessment Risk review
Delphi techniques	Questioning a large group of respondents for their opinion regarding the OR and their characteristics via a questionnaire for example (dependent on the respondents)	Self-assessment
Diagramming techniques	Developing diagrams to gain insight in the functioning of the system and its underlying weighing of aspects; examples are the *Cause and effect diagrams, System/process flowcharts, Influence diagram and SWOT analysis*	Self-assessment

6.1.3 Data collection management – Risk manager

When approaching RM through the self-assessment approach, a facilitator with appropriate skills is required to support the staff whilst analysing the risks. According to Kenzo Oijevaar (Appendix B.4) the managerial and facilitating role during the RMP is a task appointed to the risk manager. The risk manager's foremost role is ensuring that the required information and expertise is collected at the right source and pursuing actual implementation of the collected data. During the tender phase the risk manager will collect the data through risk sessions with the support of the tool; the time in the tender is limited, thus the project is not yet iterative at this point in the process. Conducting these sessions with logical, subject-based (discipline) groups doesn't turn the process into an obligatory exercise and steers each sessions to the required category in which risks might reside. Opportunities and threats are discussed specifically by pointing out project elements; actually mentioning the words opportunity and threat also tilts the thinking process of the users in that direction. Once possible enhancements or improvements are identified, measures are developed and turned into actions. The sessions also allow for questions in case of un-clarities, creating a conversation instead of an one-direction information flow. The final conclusion of the sessions is presented to the tender manager. This conclusion encompasses the measures and the actions that follow, providing input on which iterative design steps can be made. From this point on forward, the RMP transfers from RA towards RM; iterative implementation of measure-based activities points out the need of management.

The need for management is also endorsed by Harwil de Jonge (Appendix B.5), indicating the need for an active user and promoter to ensure usage of RM in the process. Either a risk, project or tender manager should take the responsibility of ensuring a proper RMP, based on the phase in which the project resides; experience shows the RMP comes to a standstill otherwise. Getting accustomed with the tool and maintaining focus on RM are essential. To support the usage, the tool should remain accessible; too complex or extended and none of the users will provide adequate or required information. One way to ensure usage is a strict format, however experience has shown that conducting brainstorm sessions with the entire team with an open category-based document yields better results. Taking a proactive stance opens the way for discussion.

6.1.4 Tool-based output

By taking an active stance and deploying actions based on the phase in which the project resides, the manager is capable of collecting the data required for the RA. The collected data is stored accordingly in the documentation provided by the tool. Whilst documenting, all gathered knowledge needs to be turned into clear risk descriptions and quantified information, here the fuzzy logic proves its usage by transforming the vague descriptions into the mentioned quantities for the factors money and time. Currently, the entire model is based on a (limited) questionnaire and several assumptions to limit the extent of the research. In order of judging the model's functioning, both verification and validation need to be applied. Simultaneously, both can be used to explain how the information from different sources can be documented; besides a testing function, the verification and validation also fulfil an explanatory role for the future user.

6.2 Verification

Judging the tool's performance is done through verification. For this purpose a small exemplary case has been conceived. Simultaneously it is used to explain how to document the risk description and other characteristics in the correct manner. Especially the description is of importance since it contains the cause and impact as well, thereby forming the baseline for the following control and/or response measures.

6.2.1 Verification case

For the verification case, a few risks were devised based on the subject *'energy management'* and the maintenance and operating aspects of a DBFMO-contract. As first, the project was assumed to be limited to €1.000.00,- with a duration of 50 days. Because of the exemplary function, the number of risks has been limited to a total of eight risks. These risks have been manufactured with a full coverage of different natures, categories and statuses in mind. In order of performing an actual validation, several of these parameter are toggled into different scenarios; the main focus of this validation is to judge whether the resulting numbers are applicable or suitable for further developments.

Table 6.2: Overview of the eight conceived risks as documented in the tool, the editor is left out for simplicity.

No.	Tag	Description	Nature	Category
1	Ventilation capacity	Standard calculation schemes create buffers, ventilation capacity far exceeds the required volume, Initial investment for the installation is far too large because a smaller one would have been sufficient	Optimization	Mechanical installation
2	Warranties suppliers	DBFMO contract thus including maintenance thus warranties needed for the long term applied elements, warranties not covering for the entire M & O term of 20 years, additional maintenance and repair expenses	Threat	Contractual
3	Energy monitoring system	Design has no usage of energy monitoring systems as of yet, place the monitoring system to gain insight in the usage, reduced energy usage followed by lower operating cost	Opportunity	Electrical installation
4	Curved iso. glazing	Curved isolating glazing unproven in usage, possible defects requiring repairs or replacement, additional expenses at maximum of original construction cost	Threat	Construction
5	Isolation existing structure	Existing wall poorly isolated, EPC performance compromised, additional isolation is required	Threat	Construction
6	Quality wooden cladding	Low quality timber cladding, higher quality will require less maintenance and possible replacement, long-term less expensive in LCC	Optimization	Construction
7	Heat exchanger	No heat exchanger present in the ventilation system, placement leads to reduced loss of heat thus decreased heating, lower operating cost	Opportunity	Mechanical installation
8	BREEAM loan extension	Additional bank loans achievable, loans provided when the design complies to the maximum BREEAM score, additional financial benefits for the realisation	Opportunity	Financial

6.2.2 Verification outcome

The eight conceived risks haven documented in the tool, as shown in Table 6.2, and are complemented with additional characteristics. The results of this verification case are shown in Appendix F. Based on their nature the eight risks can be divided amongst three opportunities, two optimizations and three risks; Figure 6.1 shows the outcome spreads for the opportunities. It is assumed that this is the initial identification, thus all opportunities and threats are ongoing, whereas the optimizations are still to be applied. Considering the spread of the risks along the different categories, the notion that creating a sustainable building is an integrated task for the entire project team is endorsed by the coverage of nearly all risk categories.

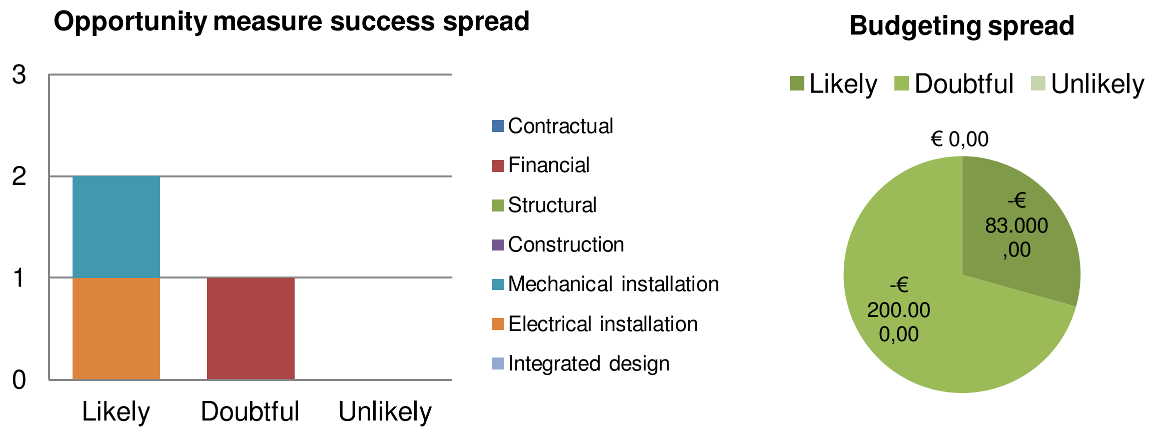

Figure 6.1: Outcome of the SLC's and budgeting for the opportunities in the verification case

In the following assessment, the characteristics of six out of eight risks was deemed certain. The characteristics of these known risks were documented, e.g. the extension of the loan based on the achieved BREEAM score is an opportunity with a known financial benefit of €200.000,-. Although this amount is a loan, it allows the contractor to develop the additional sustainable features of the project even though the client does not the required financial resources at the start of the tender procedure; the contractor can offer additional value based on higher investment without having to rely on the client directly for resources. The two uncertain risks are estimated via the fuzzy logic principle. In case of the wooden cladding, the quality of the product means an increase in the performance, whilst reduced maintenance foresees less hindrance for the environment both in term of direct hindrance and a reduced environmental impact since less wood is needed over time. Less maintenance also means placing both the surroundings and the workers in dangerous positions less often, e.g. high up on the façade, thus decreasing safety issues. These assumptions have been interpreted as shown in Table 6.3.

Table 6.3: Assumed size of impact for the uncertain risks, interpreted on the effect on the project's objective functions

No.	Tag	Nature	Certainty check	Quality (%)	Environment (hinderance) (%)	Safety (%)
2	Warranties suppliers	Threat	Uncertain	50%	0%	20%
6	Quality wooden cladding	Optimization	Uncertain	60%	20%	20%

These assumptions are used as input to calculate their size of impact through fuzzy logic. Table 6.4 shows the outcome for the two uncertain risks. Since risk 2. is a threat, the outcome means an increase for the required resources, hence highlighted in red. Risk 6. is an optimization which is still 'to be applied', hence the highlight is green in colour; the optimization is still a beneficial option resource-wise relative to the current design.

Table 6.4: Outcomes of the FL operations on the two uncertain risks, extended with the SLC of their control measure

No.	Tag	Control measure succes likelihood	Risk budgeting (€)	Planning impact (days)
2	Warranties suppliers	Doubtful	€ 22.320,31	2
6	Quality wooden cladding	Likely	-€ 30.030,39	-2

With the characteristic known for each risk, control measure are developed and documented. If a control measure requires investments, these have to be noted along with the target department in charge of implementing the measure. Finally each of the measures are placed in a SLC (Table 6.3). In this step of the verification, the first malfunction was encountered as well. One of the risks, 'isolating the existing structure', has received no control measure and solely relies on a response measure. This means that the full impact in terms of money and time should be taken into account in terms of the budgeting, hence the SLC should encompass a '*none present'* category at a locked value of 0%. After the control measures and their likelihoods, the response measures are developed and documented in an equal manner. In many a case, this control measure comes down to performing additional calculations or tasks; in some cases it specifically targets the mitigation of the impact, e.g. request additional knowledge regarding the treatments and repair possibilities of the curved glazing as has been gathered over time.

The documented information is effectively transferred to the RMS. Each of the risks are divided based on nature and categorised through both the SLC and category. Even though a limited number of risks has been applied, conclusion can still be drawn from the statistics as well as the graphs. The highest financial impact is generated through the opportunities at -€283.000,-, as can be seen in Figure 6.1. For two out of three of these opportunities, the SLC is likely, this indicating a high likelihood that the stated amount is obtained at least partially. For two out of three risks, the control measures are placed in the unlikely SLC, thereby resulting in a high likelihood that the actual risks should occur, characterised by €192.320,-. The optimizations are currently still 'to be applied', hence their financial impact €55.030,- is seen as decreasing for the total risk budgeting. On side B of the RMS values for the SLC's are determined in order of obtaining the spread values. For this case the values have been assumed: likely 90%, doubtful 60 % and, unlikely 5%. Automatically following are the scenario spread for both money and time for which the confidence intervals can be determined based on the level of risk acceptance. At this stage, the second malfunction was noted. Originally the calculation of the interval relied on σ as the standard deviation resulting from the MCS, this spread however is incomplete due to the missing worst-worst and best-best scenario in the spread. Therefore the applicable σ is taken from the scenario spread and used as input for the calculation of the confidence interval. For the confidence interval the acceptable risk levels were assumed at 10% for money and 5% for time, thus indicating that there is an increased desire to obtain this project but with limited risk acceptance. The outcome interval for time is then transformed using the discount or bonus for planning deviations, resulting in the total project risk budget. This budget is placed in a spread ranging from -€77.300,- for the lower bound, -€72.205,- for the average budget and -€67.109,- for the upper bound, shown in Figure 6.2. From the value we can see that it if the given opportunities are seized and threats are mitigated, that the risks would actually lower the risk budget to such an extent that it would turn out as a additional profit.

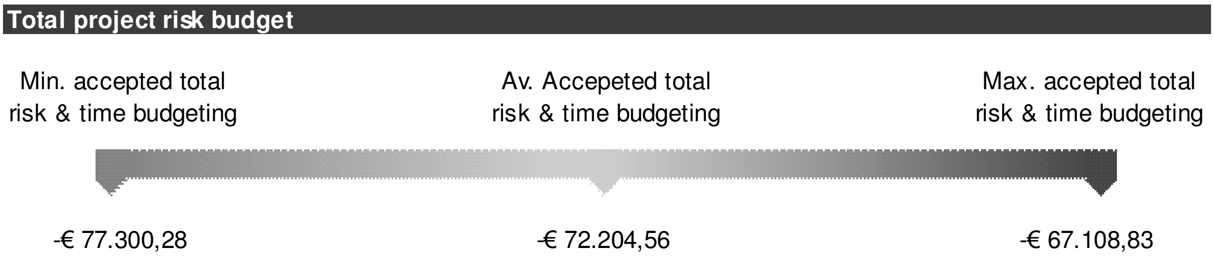

Figure 6.2: Total risk budget spread, adjusted to the planning impact and acceptance

Two additional steps were taken to validate the tool. The first step is adjusting the risk acceptance; higher levels of risk acceptance should mean a decrease in the total project risk budget spread, with lower levels extending the bounds[9]. For the verification a 1%-1% test and a 30%-30% test were simulated. A cross comparison is then performed along the initial 10%-5% selection. The 1%-1% test results in a spread with Δ(mean-min; max-mean)=€7.691,- and the 30%-30% test leads to Δ(mean-min; max-mean)=€4186,-; for means of comparison, the Δ for the initial selection is €5121,-. This means that the assumed functioning of the risk acceptance confidence interval calculations is adequate. The second step is setting the optimizations' statuses from '*to be applied*' to '*applied*', which should turn the financial impact from negative to positive thus adding to the size of the total project risk budget. Running the calculations and simulations after the altering the statuses, the budget is placed in a spread ranging from -€7.948,- for the lower bound, -€2.819,- for the average budget and €2.309,- for the upper bound, shown in Figure 6.3. With this spread, the risks would still return a profit rather than a reduced margin, though the size has decreased significantly.

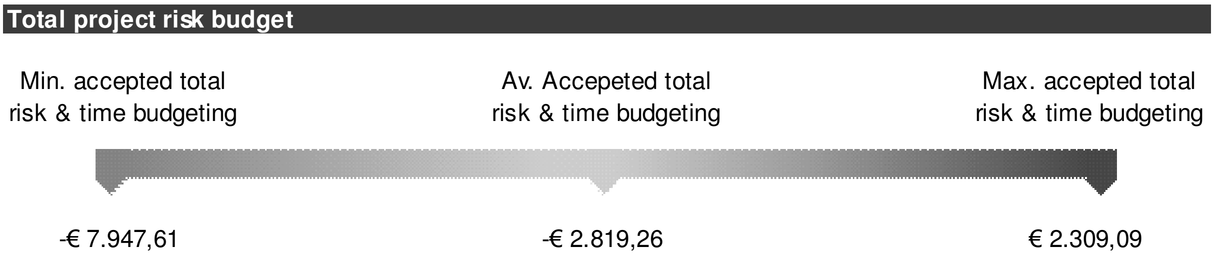

Figure 6.3: Total risk budget spread for the verification case, optimizations set to 'applied'

With this verification case, the functioning of the tool has been proven. All inputs are structured in a clear list with filtering for each aspect; all inputs are transformed into financial descriptions; and, the resulting statistic are compiled on a single, one-page output. One important notion for this model, the outcomes of the simulations will always come up with a fluctuation; after each simulation, the total project risk budget will be deviate from the previous value in a limited spread.

[9] The confidence interval explains the bounds between which there is a P certainty that the actual value is part of the spread, lowering the acceptance (P^{-1}) results in a higher P thus a large spread

6.3 Validation

With the functioning of the tool verified, next would be to validate whether the process and the tool provide the information requested by Heijmans. For this purpose, an equal approach as for the verification was adopted though with a different case. This case is an actual case performed recently or still in progress. The aim is to see whether the renewed framework based process and especially the tool provide new insights. The comparison required for gaining these insights revolves around the original outcome and the result of the renewed tool.

6.3.1 Validation case

The project which has been selected to serve as case for the validation (from this point onwards indicated as '*project*') is a combined tender for both the construction and installations. The project's cost are in between €37.500.00,- and €42.500.000,-, with a size between 40.000 and 50.000 m^2 and the duration of realisation has been assumed at 300 working days. For the documentation a price of €40.000.000,- has been assumed. For sakes of comparison the source documentation has been deemed final at the end of the tender procedure. All documented risks have been transferred together with their characteristics and measures, resulting in the filled out tool as shown in Appendix G.

6.3.2 Validation outcome

From the RMS-Statistics the basic statistics can obtained fairly easy. In the project 4 opportunities, 7 optimisations and 50 threats have been identified. All opportunities' SLC's have been assumed likely and are estimated at a total of -€443.765,-; for the optimizations the estimated outcome is -€1.444.071,- with the measures mostly assumed likely, and; the total unadjusted impact for the threats is €8.159.097,- with half of the measures perceived as likely and nearly the complete other half as doubtful. From these figures, as shown in Figure 6.5, it becomes clear that the emphasis should be placed on reducing and mitigating the project's threats.

For the risk features on the RMS-Budgeting, the following values have been given: likely 90%, doubtful 50%, unlikely 10%; money-risk acceptance 10%, time-risk acceptance 5%. These initially broad boundaries have been selected since scoring the project is of importance for installations, nevertheless has the acceptance for time been reduced due to the hefty fine on project overrun; this fine is €5000,- per calendar day, no bonus present. These values have led to the total project risk budget spread over €1.523.680,- for the lower bound, €1.615.878,- for the expected value and €1.708.076,- for the upper bound, shown in Figure 6.4.

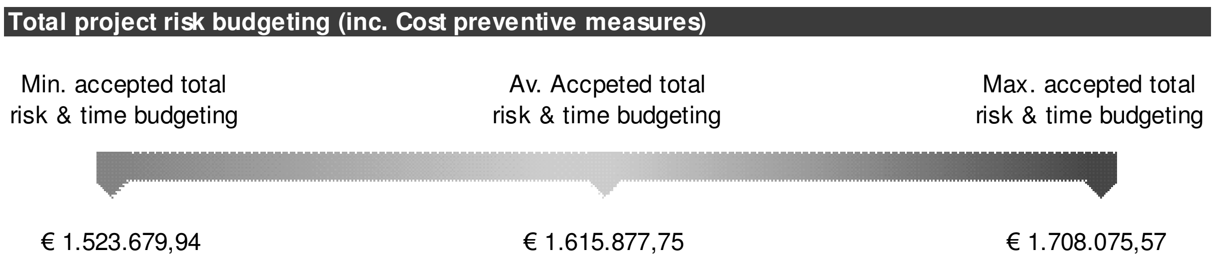

Figure 6.4: Total risk budget spread, adjusted to the planning impact and acceptance

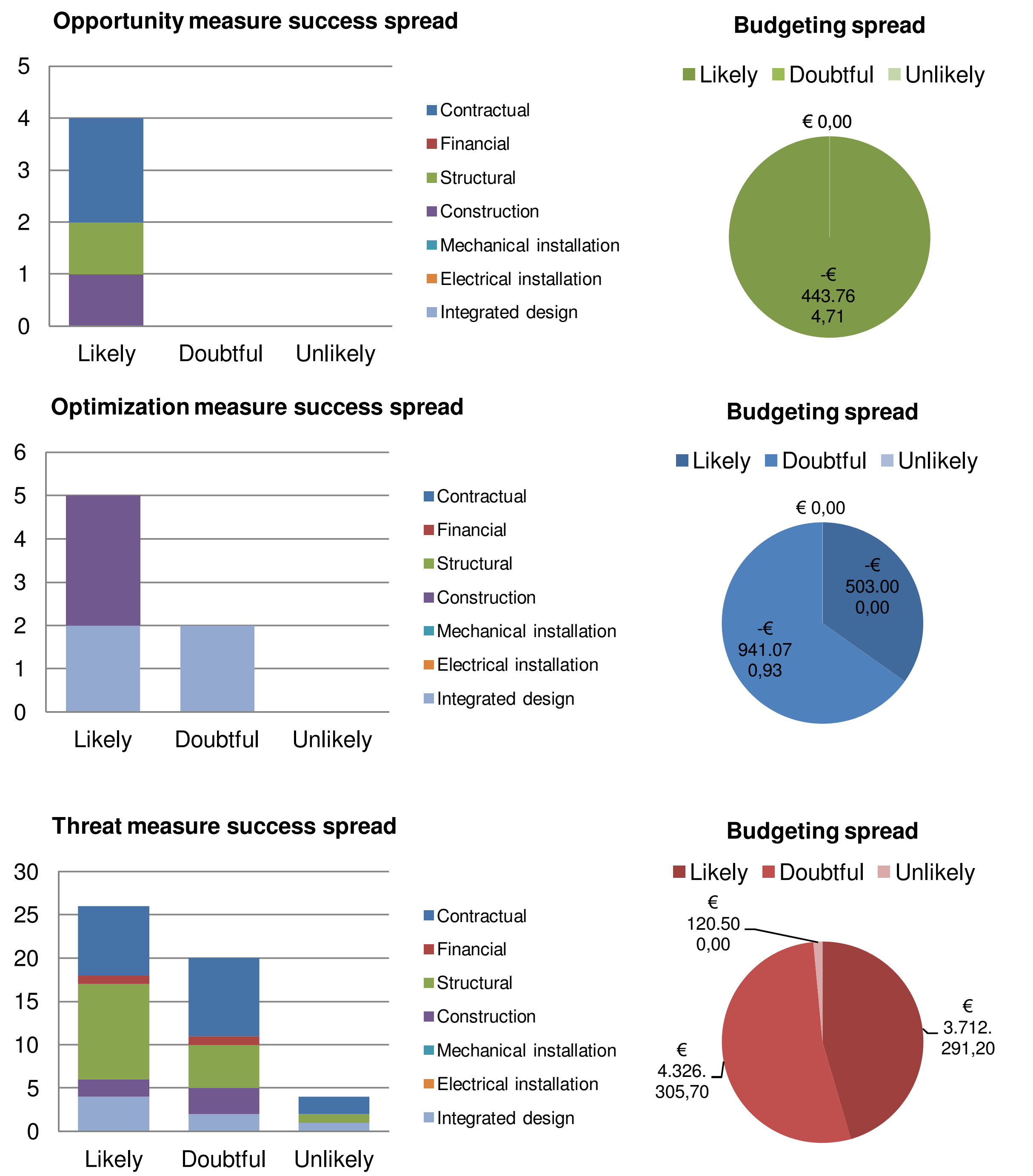

Figure 6.5: Outcome of the SLC's and budgeting for the opportunities, optimizations and threats in the validation case

For the source documentation the unadjusted risk budget was assumed at 1.450.000,-, seemingly close to the expected risk budget as proposed by the new tool. However, the old method relied on the assumption that risk should be quantified by multiplying the size of impact with likelihood, thereby ending a risk budget of €60.000,- (!) on a project of €40.000.000,-. The outcome of the new tool indicates that the proposed risk budget makes up 4% of the total project cost and effectively covers half of the margin limited to 8%. This indicates that project proposes a mediocre risk for the organization; margins will be small but present leading to profit. Maintaining this profitability strongly depends on successfully implementing the optimizations, simultaneously it is recommendable to direct some additional attention to the threats placed within the SLC doubtful.

From these figures obtained from the documented information, it is evident that the tool is capable of pointing out strong points and points of attention, whilst simultaneously providing the user with a realistic budget assumption, together with indications on where to place additional attention when whilst trying the improve the measures. This combination of simplicity, traceability and probable outcomes underpins the usefulness of the tool.

Though the tool has proven to be useful, the verification also pointed out additional issues. Aside from the malfunctions during the noted during the validation, these issues require attention when further developing or applying the tool. First the source of the assessment input is important. In case of a certain value, noting the sources allows for future referencing and traceability. When the characteristics are deemed uncertain, the risk editor is the source upon which to rely in case of misunderstandings or incomprehension. Noting the name of the editor again endorses the traceability. Secondly, the input factors money, time, quality, environment and safety are well suitable when assessing an elemental or project risk. However in case of contract-based risks these factors do not cover all aspects, disabling the ability to quantify the risk. Third, some risks do not have an impact on the final risk budgeting, but operate on a higher level of abstraction being go-no go decisions and scoring the tender. Though these risks can be noted in the documentation, the influence on the final budgeting is limited to none. Perhaps an additional nature should be added to indicate these specific threats. Fourth and final is not as much an issue as a notion; the combined cause-risk-effect description allows for simpler documentation, however it also reduces the ability to direct the measure towards a clearly defined cause. The most suitable cause of action is applied trial and error to see which one of the layout is most suitable for the future user.

6.4 Conclusion

Collecting and storing data regarding the risks requires additional actions that fit within the proposed framework and subsequent tool. Since this information can be gathered from different sources, at different moments during the process, it is important for the person in charge of RM to select an action most befitting the desired risk information and state of the project. Several actions have been proposed, divided amongst risk review and self assessment. In case of the former, a selected team with the sole focus on risk is appointed to assess all risks within an organization. The main approach is gathering the information from experts within the organization combined with additional risk assessment tools. Self assessment is performed by a the project team itself, performing RM as a part of the entire project or process development. Modes of assessment for this approach commonly encompass brainstorm sessions, questionnaires and diagramming techniques.

Through validation and verification, the functioning of the framework-based tool has been proven. Though some alterations are in order for further tuning of the tool, the results thus far prove to be realistic with a clear overview. The outcome of a fully filled documentation allows for the assessment of risk entities, their spread and impact on the project's objective functions. By transforming all inputs into financial impact estimations, the full budgeting can be determined which is set alongside the margin for comparison. The latter action allows for the judgement whether or not the project is '*high risk*' or a decent opportunity. With this proven status of the description based framework and tool, the research foresees in a renewed RMM covering both the process and project aspects of RM.

7 Conclusions and recommendations

The research described in this report focussed on the RMP. Parts of this focus where the underlying definitions, a structuring framework and a supportive tool. With the results of the research shaped by these elements at ones disposal, the research question [RQ] and the sub-questions [SQ.1-5] can be answered. Based on the answered outcome, a discussion is performed on whether a solution has been provided for the problem statement [PS]. Finally, the research is closed with recommendations regarding the developed RMM and the applicability and the possible future directions subsequent to or in conjunction with this research. This chapter starts by providing an answer for the sub-questions, followed by the research question. With those answers in place the discussion regarding the problem statement is performed and finally the recommendations are provided.

7.1 Concluding sub-questions

Providing concluding answers for the sub-questions is a prerequisite of answering the research question since the latter has been split in to several sub-questions covering specific, single sub-topics. For this purpose, each of the sub-questions is addressed separately.

7.1.1 Sub-question 1 [SQ.1]

[SQ.1] 'What are the reasons of the dysfunctional state of the current method?'

The answer for this sub-questions has been provided by the problem analysis in chapter 2. Through analysis of the currently applied method, user feedback and comparison to other methods deployed within the organization, the problems causing the dysfunctional state have been identified. These causes are as following:

- No equal focus on both risks and opportunities;
- No iterative process, developed measures are barely put into use;
- Due to insufficient knowledge users are incapable of providing a uniform team effort;
- Without an overarching strategy, RM lacks a predefined purpose.

From these notions it becomes clear that achieving the desired state and usage of RM relies on the understanding of its users and a framework-tool combination to support the user's actions during the process. By linking the identified problems to the following sub-questions, targets were stated to steer the progression of the research in the desired direction.

7.1.2 Sub-question 2 [SQ.2]

[SQ.2] 'Which methods are currently available for structuring the RM process (RMP) and which one/ones are most suitable for future use in the construction market?'

Answering this sub-question requires the outcomes of both chapter 3 and 4. The former is conducted to provide the correct definition for the term risk, and all subsequent terms, in case of project management. The most important notion is that risk encompasses both opportunities and threats and risk itself indicates no more than the uncertainty of manifestation set against a likelihood. In this definition, the common assumption of impact times likelihood is rejected. Although this multiplication provides the ability to prioritize, it creates a lopsided risk quantification unbalanced relative to the reality. With the renewed definition, opportunities and threats are treated in an equal manner foreseeing in a solution for the first identified problem. Through the balanced definition, all actions direct towards the management of risks uphold a uniform focus.

In the same chapter the terms RM and RA were identified and defined as the main principles in RM. Through these two principles, the notion of creating an iterative process has been provided, adhering to the second identified problem. The definitions also indicated the outline for the required activities for performing RM. In this the RA focuses on the identification, prioritization and analysis of the origins, influence and likelihood, or characteristics, of each project risk followed by the development of control and response measures.

These RM and RA definitions with their iterative process, are combined with the risk definitions to create a basic outline for the development of a framework structuring the process. For this framework multiple methods were assessed on their structure and their incorporated activities. From these methods the RISMAN method's structure was selected as the template for the framework due to the already foreseen (yet currently not implemented) iterative management process and the current application in Heijmans' organisation. The latter will ease the process of change once the users are equipped with the new tool during the process development. The final proposed framework is divided amongst the principles RA and RM. The selected activities for RA are risk identification, risk assessment and developing control and response measures.

7.1.3 Sub-question 3 [SQ.3]

[SQ.3] 'How can the gathered information of the structured RMP be documented to provide clearly defined arguments or metrics to support the decision making process?'

Defining the characteristics and documenting those findings is done using the framework's structure based tool as developed in chapter 5. By providing a tool that adheres directly to the activities as stated in the framework, the supportive value of the tool vastly increases. Users are now capable of following a predefined process, simultaneously storing the information gathered and created during that process. The identification foresees in the basic description for every risk and descriptive characteristics nature, category and status. Documenting the metrics, or in terms of the framework activities quantifying the risks, when the values are certain is simply done be noting the value of the impact in terms of money and time. In case the values are uncertain, the user is to estimate the impact of the risk in terms of quality, environment and safety. Through fuzzy logic these terms are transformed to values in terms of money and time as well.

With the characteristics known, the user then develops the proactive control measures and the reactive response. For both types of measure, the target division and risk owner are noted. In case of the control measures this is extended with the cost for the measure itself and the SLC. The latter explains to what the degree the user expects the measure to be effective expressed as likely, doubtful and unlikely; a successful measure means one that realizes an opportunity, negates a threat and either of the two for optimization depending on the status.

As outcome of the tool, a statistical summary is made of the number of risk entities, their spread amongst the natures, categories and SLC. Combining this spread with the cost for each nature-SLC combination, indicates where the emphasis of the project lies in terms of entities and money. It directs attention to those areas that can make the difference for the project, setting it apart from the competitors offer. The second outcome is the RMS-Budgeting, stating the expected risk spread in terms of money and time, determined via a Monte Carlo simulation for both terms. After adding the values for the SLC's and the risk acceptance or confidence interval, the total project risk budget is provided. This budget is a spread between the minimum, average and maximum acceptance adjusted risk budget.

Using the framework-based tool not only provides documents and conveys all information needed for the decision making process regarding risks, it also is simple in its use with a split between data documentation and managerial decision making. The simplicity and the split make the tool clear in its usage, creating a support for the establishment of an uniform team effort in RM.

7.1.4 Sub-question 4 [SQ.4]

> *[SQ.4]* 'How can the newly or redeveloped method support the implementation of RM by achieving the desired mindset amongst personnel?'

Creating the required mind set hinges on multiple aspects. First there are the renewed definitions of the terms risk, threat, opportunity and risk management. By embedding these in the framework, the permeate the process structure which in turn is based on a clear stepwise set of activities. Both the framework and the already embedded descriptions then form the outline for the eventual tool, having the concept fully permeate from a process, through project, to user level. This notion already provides the mindset to focus on both opportunities and threats whilst eliminating the original negative perception of the term risk.

Second the mindset is created by the manager in charge of the RMP as indicated in chapter 6. He or she has to responsibility of directing the RM process from a facilitating standpoint. Users are engaged based on their specific knowledge and team-based risk (brainstorm) session aiding in the creation of a full range identification and assessment. Combining these actions with the fully embedded descriptions, framework and tool, creates the coherent basis for the personnel to get engaged with RM. Once unrolling the entire method in the organization, the manager also has the task of encouraging the personnel into using the method; a top-down trigger is required to ensure bottom-up adoption.

7.1.5 Sub-question 5 [SQ.5]

> *[SQ.5]* 'How can Heijmans achieve the most suitable bid in terms of price and quality for the client, based on the defined risk characteristics and developed measures?'

Achieving the most suitable bid is a conjoint effort based on the conclusions of all four of the previous sub-questions. The redeveloped RM method based on the framework with the adhering tool, foresees in a process in which all involved personnel aims at the identification and assessment of the risk entities in order of developing control and response measures emphasizing the project strong points and controlling the points of attention. The outcome of the tool indicate where in the project the (additional) abilities lie to improve the project by promoting opportunities and negating threats.

The ability to improve however is not limited to just the budgeting and planning impact; creating a bid that is truly 'most suitable' for the client is putting additional emphasis on those risk entities that are perceived by the customer as highly important. An important part of the mindset when performing the RM process with the renewed method, is the aim at customer satisfaction. With the growing attention for quality through e.g. EMVI and BREEAM, the client is becoming increasingly aware of the added value beyond price and planning. Though still a large portion resides within those terms, the approach of a project should be enhanced beyond the expected value towards an extended customer value.

7.2 Concluding research question [RQ]

> *[RQ]* 'How should Heijmans either improve or redevelop their RMM to achieve the desired increase in <u>internal implementation</u> and <u>external, commercial application</u>?'

From the concluded sub-questions, it has become evident that the renewed method with the concept definitions, process structure framework and supportive tool, foresees in an increase in both internal implementation and external application. Internally the users, ergo personnel and management are handed a simplified and holistic method that provides a stepwise process structure and adhering documentation. Working with one uniform, easily understandable method, the users can now direct their focus towards the actual process rather than trying to understand the process. From a managerial standpoint the method increases traceability, thereby increasing the ability to steer and control the process. This combination of target-focus and control through traceability will increase the internal implementation of the tool.

As a direct result of the internal increase of using the renewed method, a more detailed and well documented overview can be created from all risk entities in the project. From this overview insight can be gained on how and where to create added value for the client, increasing the quality and overall customer value. This is an improvement of the external, commercial application for a single project. On long term, the increased grasp on the risks influencing each project and the ability to excel in the creation of added value will result in a competitive advantage. Combining this with the advantage with the ability to focus on margin rather than volume actually set sHeijmans apart as '*the leading building company in terms of profitability, quality and sustainability by 2015*' (Heijmans, 2012b).

7.3 Problem statement [PS] discussion

> *[PS]* Changes in the construction market result in new activities and subsequent responsibilities that befall Heijmans. Hence, the company needs to know how the risks originating from this <u>core business extension</u> can and should be managed to <u>secure profit margins</u>.

Securing profit margins is a main value provided by the renewed method. Deploying RM with the focus on the total, acceptance adjusted, project risk budget allows the ability to compare this possible financial deficit with the size of the project's margin. If the expected value of the spread, and for additional certainty the worst-worst scenario in terms of money, is less than the total margin the project can be considered profitable. This is endorsed by the notion that the budget is calculated with every risk entity in mind, while in reality is likely that not all if not most of the risks do not even manifest themselves during each of the project's phase; in case a risk does not manifest, the reserved financial resources can be considered as profit. Or in the opposite case, if the required total project risk budget exceeds the margin, the decision making unit has to decide whether or not to proceed with the project.

Regarding the core business extension, the renewed tool is generic to such a degree that whatever the nature might be of an identified risk it can be documented and assessed. Due to the ability to quantify both certain and uncertain values, it makes no difference whether previous knowledge or understanding is present in the project team or overall organisation. This means that no matter what the additional task might be for Heijmans or any other future user of the method, the risks involved can be analysed and managed; the assumed size and nature of the possible risks involved with the extended activities or of course a whole different matter. Each risk might oppose a whole different impact per organization, hence the values added are most depended on the perception the user and the culture.

7.4 Recommendations

Though the research has provided a holistic RMM, is was also a first attempt at combining the theoretical methods with the practical notions and experiences of engaging in RM during the entire project life cycle. Due to this being an early attempt, additional research might be desirable to e.g. provide extensive validation and calibration of the tool. In order providing future research on the topic of RM in the expanding construction market, the following section will state recommendations. As mentioned afore, these recommendations are divided between the developed RMM and the applicability on one hand and the possible future directions subsequent to or in conjunction with this research on the other.

7.4.1 Research continuation recommendations

The foremost recommendation when continuing the research with the developed method is 'validation, verification and calibration'. Validation points out that perhaps more terms are required to fully cover the impact that a risk might have. In this research the terms were limited based on the predefined GOTIKV terms. In reality however, it might be that far more terms (or less for that matter) might by encompassed by risk impacts. With an increase of terms comes the capability to quantify risks increasing in both number and complexity.

Verification regards the testing of the method's elements in ongoing or starting projects. Having users actually performing RM via the proposed framework and the documenting the gathered data with tool, generates direct user feedback on difficulties. It also creates indirect feedback when certain parts of the tool are used in an unintended manner. Only if tested in an ongoing project can the value of the method be tested to the fullest. Special emphasis must be placed on the risk descriptions and the assessment to ensure that all activities are performed as intended.

Calibration is the process of adjusting and correcting the values used for the calculations and logical operations in the tool. Many of these numbers so far are based on assumptions. The response that were gathered through questionnaires were so low in number that those still require adjusting. Since the quantification of exactly those risks which are of importance due to their uncertainty is a major component of the method. Having them perform using non-calibrated could lead to skewed outcomes. Optimisation of these values in order of ensuring the proper functioning of the tool and thus the method.

7.4.2 Research extension recommendations

Extending the research regarding RMM's and their practical application can be done in several directions. System engineering (SE) is increasingly applied in the construction industry and has proven to work well in combination with RM. First of all, semantic databases can be used to store all the information, a documentation system in an open environment improves simplifies communications during integration. But more importantly, SE directly links risks to the element upon which they express their influence or by which they are influenced; when an object is handled or altered in the SE environment, the adhering risk automatically shows, providing extensive insight per risk. Simultaneously the SE environment also allows the manager of the current phase to judge which measures have been implemented or require additional attention, provided through checklists. Since these checklist also contain the measure owner, the manager is also capable of retracing the cause in case of a setback.

A second option would be to introduce chain management; the impact one risk has might very well be the influence for the next risk. Developing chains of succession and analysing the subsequent impact of each entity in the chain, determines where the biggest impact stems from in the system. If a single risk event is leading for all other risks in the chain, it is far more efficient to focus on controlling that specific risk rather than trying to control all risks separately. Such a risk chain can be devised by using system dynamics (SD). Developing the most suitable bid is then done by simulating and comparing scenarios using SD with the predicted magnitude as input. SD is introduced to consider the complex interrelated structure of risks following the many factors influencing them (Nasirzadeh et al., 2008). SD is a modelling and simulation method, allowing for the analysis of (industrial) systems by representing them in a model showing the feedback processes, which along with stock and flow structures, time delays and nonlinearities determine the dynamics of the system. (Sterman, 2000).

Finally, a database can be created to store all risk information compiled during the RMP. Eventhough projects are unique and location bound, many of the risks are reoccurring. Storing the empirical information regarding these risks, their measures and manifestations, creates a knowledge baseline for future projects. Estimating the characteristics can then be done using the gathered experiences, providing (assumably) certain figures. Storing the knowledge and experiences requires a proper database capable of such a feat without reducing the accessibility for its users.

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Appendix A
Overview of statistical analysis of single embedded case study.

	Frederikkazerne				Stadskantoor				Bèta Campus				UMC			
	Risk	Opportunity	Risk/opportunity	**Total**	Risk	Opportunity	Risk/opportunity	**Total**	Risk	Opportunity	Risk/opportunity	**Total**	Risk	Opportunity	Risk/opportunity	**Total**
Order backlog	-	-	-	**-**	10	3	2	**15**	2	1	1	**4**	5	1	1	**7**
Contractual conditions	5	-	-	**5**	13	-	2	**15**	18	1	-	**19**	13	-	-	**13**
Building process	7	-	-	**7**	7	-	-	**7**	7	-	2	**9**	11	2	-	**13**
Building product	10	1	-	**11**	31	17	2	**50**	26	5	1	**32**	14	15	-	**29**
Total	**22**	**1**	**-**	**23**	**61**	**20**	**6**	**87**	**53**	**7**	**4**	**64**	**43**	**18**	**1**	**62**
No risk	3	-	-	**3**	-	1	-	**1**	4	-	-	**4**	-	-	-	**-**
Minor risk	14	1	-	**15**	9	6	-	**15**	23	3	2	**28**	18	17	1	**36**
Medium risk	5	-	-	**5**	32	10	4	**46**	24	4	2	**30**	20	1	-	**21**
Large risk	-	-	-	**-**	20	3	2	**25**	2	-	-	**2**	5	-	-	**5**
Controllable	22	1	-	**23**	43	18	6	**67**	45	7	4	**56**	38	18	1	**57**
Uncontrollable	-	-	-	**-**	18	2	-	**20**	8	-	-	**8**	5	-	-	**5**
Risk budget	Not present				1.169.842,00				60.400,00				n/a			
Risk/Opportunity ratio	22,0:1,0				2,35:1,0				4,82:1,0				2,26:1,0			

Appendix B

Overview of all interviews taken during this research.

Notification: All interviews were held in Dutch for reasons of simplicity and 'accessibility' for the interviewed.

Contents:

Appendix B.1

Interview Frits Dirckx (Dutch), risk management, taken on 12-09-2012

Oorsprong huidige methodiek

Met de realisatie dat het uitvoeren van risicomanagement van belang is voor gedegen projectontwikkeling, is met ingang van 2000 gezocht naar een passende methodiek. Aan de basis lag de benadering zoals binnen Infra was overgenomen uit de methodiek van de opdrachtgever (RWS), oftewel de RISMAN methode. Bij latere integrale projecten is de methodiek, deels, overgenomen door de Utiliteitsbouw. Als resultaat is een eigen methodiek ontwikkeld voor Utiliteitsbouw afgeleid van de RISMAN methode. Deze methode heeft zich over verloop van tijd SMART doorontwikkeld . Daarbij zijn de eigen ervaringen uitgebreid met de kennis en ervaringen die binnen Infra eveneens waren opgedaan door te werken met deze methode. Het uitrollen en implementeren van de methode is zo geleidelijk mogelijk gedaan aangezien nieuwe werkwijzen weerstand oproept bij techneuten.

Doel van de methodiek

In essentie is het doel van de methodiek om de risicovolle situaties of objecten in beeld te brengen in toenemende mate van detail. Daarbij wordt van de mensen gevraagd een proactieve houding aan te nemen; onderkennen van het probleem, het herkennen van de risico's gekoppeld aan het probleem en het opstellen van een geschikte beheersmaatregels zijn de basis activiteiten die ontplooid dienen te worden.

Daarnaast dient de methodiek als communicatietool die binnen het team toegepast wordt. Tijdens het verloop van het project komen veel verschillende producten voorbij (bestek, calculaties, tekeningen etc.), bij deze producten worden door de verschillende teamleden aantekeningen gemaakt. Deze aantekeningen zijn echter individueel en communicatie over de bevindingen is beperkt. Door de methodiek worden deze bevindingen naar buiten gebracht en kan een dialoog geopend worden. Een dergelijk dialoog leidt er toe dat bij de opkomst van een groot probleem niet onmiddellijk de mouwen worden opgestroopt, een werkhouding die veel door techneuten gebezigd wordt, maar eerst te analyseren en te denken over een geschikte aanpak. Door kansen en risico's in beeld te brengen, te analyseren en te wegen kunnen passende beheersmaatregelen opgesteld worden. Bij sommige algemeen erkende risico's is dit niet nodig, deze kunnen direct opgenomen worden.

Overlast, kosten en investeringen

Bij veel projecten draait het risicomanagement om het beperken van overlast en kosten binnen begroting te houden. Daarbij wordt opzoek gegaan naar de bereidheid te investeren in het beperken van de overlast. Vooraf investeren in het onderkennen en analyseren van de risico's is gunstiger dan het dragen van de kosten die ontstaan bij manifestatie, oftewel "kleine investeringen vooraf leiden tot gunstige, financiële, voordelen tijdens de uitvoering". Om deze bereidheid te creëren dient de opdrachtgever niet alleen duidelijk diens wensen en de beoogde doelen te omschrijven, maar zal Heijmans ook meer informatie naar de klant moeten overleggen. Maar niet alleen de klant is gebaat bij het verschaffen van deze informatie, de omgeving van acteren is van groot belang. Veel risico's, bijvoorbeeld in de vorm van vertragingen, kunnen beperkt worden door de direct de omgeving van het project op de hoogte te brengen van de werkzaamheden. Deze benadering creëert begrip, zonder dat begrip neemt het risico juist toe door de negatieve houding die daaruit volgt binnen de directe omgeving. Hiervoor speelt omgevingsmanagement een belangrijke rol. Bij veel binnenstedelijke projecten leiden de logistiek, vuilverwerking, lawaai-, stof- en parkeeroverlast tot ongewenste situaties bij de bewoners uit de directe omgeving. Door vroegtijdig de problemen van die omwonenden te onderkennen en ze vervolgens te betrekken in de beheersmaatregelen door ze tijdig te informeren, leidt tot een positieve acceptatie van het project en de aanverwante activiteiten.

Voorbeeld: Bij de uitvoering van de Rabobank toren is er vanuit de directievoerder veel aandacht besteedt aan het informeren en betrekken van de omgeving, de laatste heeft dit als prettig ervaren. Hierdoor wordt het risico op bezwaren geminimaliseerd door een positieve perceptie onder de omgeving.

RMO als tactisch middel

Het eerste doel van het RMO is het interne organisatie te structureren en de communicatie te verbeteren. Maar vanuit tactisch oogpunt kan het ook worden ingezet om bij de klant in beeld te brengen wat Heijmans bezighoudt doormiddel van een plan van aanpak (PvA). Opdrachtgevers, hebben vaak specifieke klantwensen aangaande de benadering van o.a. omgevingsrisico's, technische risico's. juridische voorwaarden en betrouwbare partijen (derden). Door op voorhand deze klantwensen te signaleren, kan het PvA worden ingezet om aan de klant zichtbaar te maken hoe Heijmans inspeelt op de wensen. Door de risico's goed in kaart te brengen en te koppelen aan passende beheersmaatregelen kunnen risicokosten, risico opslag, verminderd worden wat op diens beurt weer de aanneemsom reduceert. Maar het grootste belang is de sterke onderbouwing van de klantwensen doormiddel van een passend PvA dat voorziet in deze wensen. Dit vergroot de kans op gunning, gebaseerd op de geleverde kwaliteiten zelfs als de prijs niet de laagste is.

De klantwensen kunnen daarbij meer omvatten dan alleen projectmatige aspecten. Naast technische en ontwerpaspecten is er ook een toenemende aandacht voor juridische aspecten, toepassing van duurzame innovaties en de opkomst van geïntegreerde contracten. Het laatste aspect zorgt voro een verschuiving van activiteiten van de klant naar de aannemer, die daarmee naast project matige en langdurige werken ook meer verantwoordelijkheden in huis haalt. De klant is vaak opzoek naar de situatie waarin 'alles voor hem geregeld wordt en de hij ontzorgd wordt'. Bij manifestatie van een risico kan de projectmanager terugvallen op en steun zoeken bij zijn team. De verschillende disciplines kunnen gezamenlijk opzoek gaan naar een passende, gezamenlijke oplossing die in dialoog met de opdrachtgever wordt opgezet.

Voorbeeld: Voorwaarden in het bestek kunnen leiden tot kortingen op de aanneemsom in de vorm van boetes. Tijdsoverschrijding is hier een typische voorbeeld van. Bij optreden van overschrijding door vertraging volgt een boete die in verhouding staat tot de schade van de gebeurtenis. Deze schade bestaat uit bijv. de extra huur voor een andere, tijdelijke, locatie of hogere verhuiskosten. Ook de rente last die volgt uit vertraging zou kunnen worden doorgerekend aan de opdrachtnemer. Wel is het van belang om vanuit de kant van de opdrachtnemer een duidelijke afbakening te creëren. De boete zou beperkt moeten blijven tot probleemgerelateerde kosten, indirecte of gevolgkosten behoren voor rekening van de opdrachtgever te blijven.

Werking huidige methodiek
Bij het uitrollen van de methodiek werd er in eerste instantie gewerkt met een 'reeks aandachtspunten die bij analyse van het project dienen te worden nagegaan'. Deze lijst was geïntegreerd in de methode, deze is in de loop van tijd verwijderd, maar de aanhangende categorisering is behouden gebleven.

Bij de huidige versie van de methodiek is alleen onderkenning van de risico's niet afdoende, ook de oorzaak en de consequentie dienen benoemd te worden. Vervolgens worden de wordt een waardering gekoppeld aan de risico's op basis waarvan vervolgens prioriteit wordt toegekend. Hoe groter de kans dat een risico zich manifesteert, gecombineerd met de omvang van de gevolgen, hoe hoger de prioriteit. Let wel, deze waardering stuurt de aandacht, maar niet meer dan dat; 'pijnpunten worden precies weergegeven zodat deze tot hoofdzaken omgezet kunnen worden.' De waarderingsmethodiek die hiervoor is toegepast komt van RWS. Hierbij is een onderverdeling gemaakt in de beheersaspecten, namelijk G(eld), O(rganisatie), T(ijd), I(nformatie), K(waliteit) en V(eiligheid) of GOTIK(V). Per risico kan geïnventariseerd worden op welke beheersaspecten deze effect heeft bij manifestatie. Ook hier kan prioriteit worden toegekend, zodra een risico invloed uitoefent op alle fronten zal deze veel aandacht behoeven. Zodra al deze aspecten goed omschreven zijn, kan de vormgeving van de beheersmaatregelen eenvoudig tot stand komen. Personen die niet betrokken zijn geweest bij het in kaart brengen van de risico's, zijn instaat om beheersmaatregelen te ontwikkelen en uit te voeren op basis van een duidelijke omschrijving. Daarnaast duidt een dergelijke omschrijving ook meteen richting aan voor de oplossing, hier kunnen vervolgens weer eenvoudig acties aan gekoppeld worden.

Zodra de beheersmaatregel bepaald is, kan deze verwerkt worden in de kostprijs doormiddel van becijfering. Daarbij wordt er afgewaardeerd voor 'unknown unknown' risico's. Alle kosten bij elkaar vormen de risicopost. Daarbij wordt ook ingeschat in hoeverre de opdrachtgever meedenkt in het proces, de aard en kwaliteit van de opdrachtgever zijn daarbij van belang. Een proactieve opdrachtgever zal actief meedenken in het behalen van een acceptabele risico post, daarbij is het mogelijk de kostprijs sterkt te doen dalen.

Bij het opstellen van de waardering geldt dat eerst de orde van grote, prioriteitsstelling, wordt bepaald aan de hand van de bovengenoemde stappen. Vroegtijdig in het traject wordt voor de becijfering een inschatting gemaakt van de kosten die aan een risico kleven op basis van kennis en ervaring. De begroting dient bij het concretiseren als onderlegger. Het uiteindelijk doel daarbij is het kaart brengen van de middelen die nodig zijn om de risico's te verzegelen; 'Met goed projectmanagement, waar risicomanagement een onderdeel van is, kan het risico-opslag beperkt worden door goede beheersing.'

Sterke punten
Goede, diepe doorvoer van communicatie is de eerste belangrijke verbetering die voortkomt uit de methodiek. Door het tenderteam te verplichten tot risicomanagement kan vervolgens de vergaarde kennis worden overgedragen aan de voorbereiding en de uitvoering, het vroegtijdig in kaart brengen wordt daarmee bewerkstelligd.
Verkrijgen van een goed 'onderbuikgevoel' (gut feeling) beweegt steeds meer klanten om EMVI toe te passen bij een aanbesteding en dit is het tweede sterke punt. Juist deze benadering biedt de mogelijkheid om een projectgerichte aanpak uit te rollen die gestuurd

wordt op onderkenning en de beheersmethoden. Vooral de GOTIK(V) elementen zijn van belang om deze sturing mogelijk te maken. Bij het onderkennen van deze elementen is de kwaliteit van informatie van groot belang. Hoge kwaliteit kan behaald worden door de verwachtingen van de klant goed in kaart te brengen.

Om de verwachtingen te kunnen realiseren, moeten concessies gemaakt worden. Deze concessies worden momenteel echter nog niet voldoende besproken. Dit leidt tot halfwaardige oplossingen waarin vervangende maatregelen niet doeltreffend zijn en in hun beurt weer in nieuwe bedreigingen creëren.

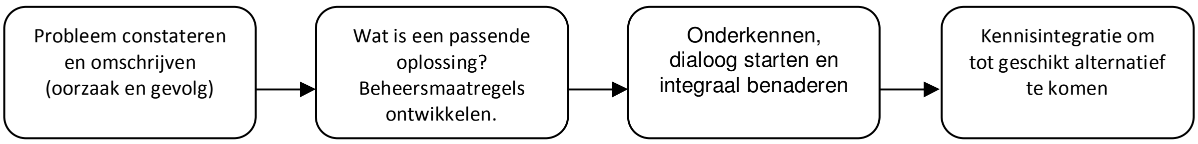
Verantwoordelijkheden, risico's en kansen

Door de verschuiving naar D&C en GCV zijn de risico's die kleven aan het projectmanagement verschoven naar de opdrachtnemer. Vanzelfsprekend is falen tijdens het project dan ook voor rekening van de aannemer. In het totale proces spelen daarbij twee belanghebbers, de opdrachtgever en de aannemer, alles daartussen is *ruis*. Vanwege deze verschoven verantwoordelijkheid is het voor de aannemer nu van belang om alles wat beheersbaar is op te nemen en de rest terug te leggen daar waar het beheerst kan worden. Zodra de invloed op de desbetreffende beheerskwaliteiten toeneemt, dan kunnen de risico's opgenomen worden. Ridicule eisen bijvoorbeeld worden doormiddel van overleg omgezet naar acceptabele, werkbare eisen. Door het aanknopen van een dialoog met de opdrachtgever of de eiser kunnen de risico's beïnvloed worden.

Momenteel wordt er in de methodiek gerekend met negatieve elementen, de kans dat een risico geld kost. Tegenoverstaand kan er ook gedacht worden met positieve elementen, denken in kansen die juist bezuinigingen realiseren. Ook hier is juist een dialoog met de opdrachtgever, en andere betrokkenen, voor nodig.

Risicomanagement Integraal

'Risicomanagement is alles omvattend, maar het is niet meer dan een instrument. Bouw is echter zo complex en integraal dat meer communicatie nodig is om alle informatie te delen.' Origineel is de huidige methodiek opgepakt om kwaliteit binnen de organisatie te waarborgen. De verbeterde communicatie speelt daarbij een rol. De integratie is daarmee wel in gang gebracht, maar het kan beter. Momenteel staat er veel op papier over de risicomanagement en de methodiek, het vraagstuk is echter waar de kansen liggen. Het stappen schema in figuur 1 vormt daarvoor de basis.



Figuur 1: Stappenschema van de integrale benadering

Bij de ontwikkeling van de methodiek heerst echter één belangrijke gedachte: 'Het instrument ligt bij de gebruiker'. De methode en de achterliggende gedachte komen niet tot recht als het werk aangaande het RMO wordt uitbesteed.

Appendix B.2

Interview Martin Schellekens (Dutch), Heijmans PPP, taken on 22-11-2012

Hoe wordt binnen Heijmans PPP omgegaan met risicomanagement (RM) en welke methode wordt daarbij gebruikt?

Bij geïntegreerde opdrachten (DBFMO) verzorgt Heijmans PPP (HPPP) de acquisitie en het procesmanagement voor de afdelingen Infrastructuur of Utiliteit. Daarbij draagt HPPP zorg voor 1) de juridische aspecten vanwege de uitgebreide contractvorming (UAV GCV) samen met de uitbreiding van de verantwoordelijkheden voor Heijmans, en 2) het benaderen van (mede-)investeerders om te voorzien in de benodigde financiële middelen. Vanuit deze overkoepelende procesmanagement functie heeft HPPP geen eigen methodiek om RM te realiseren. Het zelf ontwikkelen van een methode en die opleggen is geen optie. De bedrijfstromen zelf gaan over de 'business' en het RM is vooral inhoudelijk, zij bezitten de kennis over de DBMO-componenten komende vanuit Utiliteit of Wegen. In de processen wordt dan ook gebruik gemaakt van de risicosystematiek van één van de twee bedrijfstromen. De F-component die kan daar vervolgens wel in verwerkt worden. Daarbij is het dus wel van belang om zicht te hebben op de desbetreffende systematiek en de werking er van. Daarnaast werken verschillende methoden/systematiek averechts op het creëren van een integraal proces, er bestaat dan geen eenduidigheid in de benadering. De risico's en kansen gezien binnen HPPP zijn makkelijk te verwerken in de systematiek.

De methodieken an sich zijn niet zo spannend, RISMAN is een goede methodiek. Belangrijker zijn de vragen 'Wat doe je er mee? Wanneer doe je er wat mee? En wie doet er wat mee? Wat verwijst deels al naar de methode. Om te beginnen met wanneer, RM moet vanaf dag één. Kijkende naar de verschillende blokken in het proces, zoals weergegeven in figuur 1, betekent dat de start in Blok 1 – Kansen ligt. In de prekwalificatie fase, wanneer het aantal teams nog ongelimiteerd is (N=X), is RM nog niet van belang. Maar zodra Heijmans bij de aanbestedingsselectie zit, zou risicomanagement moeten beginnen. Momenteel richt RM zich meer op de voorbereiding (Blok 2) en de uitvoering (Blok 3), maar het zou aan het begin van de tenderfase (Blok 1, verwerving en advies) al aan bod moeten komen. In die tenderfase zie je namelijk nog veel vrijheidsgraden die ontwerpbeslissingen met zich mee kunnen brengen. Na het winnen van de tender is in de voorbereiding het aantal graden al afgenomen, maar is er nog sprake van allerlei optimalisatie mogelijkheden. In traditionele termen geeft dit de overgang weer van VO naar DO en uiteindelijk UO.

Om dan in te zoomen in de tenderfase, zoals weergegeven in figuur 2, is deze vervolgens ook op te delen in verschillende stappen. Vaak verdeeld richting klant met een aantal dialoogfasen met als uiteindelijke doel je 'best and final offer' (BAFO). In deze fase zit veel creativiteit en hoe ga je nu als tenderteam met elkaar om? Je begint met een compact team. Naarmate het ontwerp meer vorm begint te krijgen, kunnen steeds meer mensen betrokken worden om de verschillende disciplines uit te werken. In het begin ligt er alleen een vraagstuk voor een gebouw, maar wat wil de klant nou precies? Om te beginnen ligt er een concept, vanuit dit concept kan een contour en vervolgens een massa ontwikkeld worden. Deze massa wordt ingevuld tot er een VO ligt, waarna een installateur en een bouwkundige etc hun specifieke expertise kunnen toevoegen. In dit proces kan de visieontwikkeling heel erg compact, maar daarbij is maximale creativiteit vereist. De volgende stap is het inkaderen van het project waarmee over de tijd het aantal ontwerpvrijheidsgraden teruglopen en de complexiteit toeneemt.

De vraag is nu: wat is in die tenderfase, en niet de voorbereiding, de rol van RM? Maar of het vanaf dag één moet? Waarschijnlijk is RM ook een toenemend proces over de tijd. Het gevaar schuilt hem daarbij in het doel van RM in deze fase. Gaat het om het behoeden van fouten? Of om het zien van kansen? Vaak gaat het alleen maar om het zien van de ellende, terwijl juist in de beginfase van een tender er een focus moet zijn op kansen (vanuit de voorliggende uitvraag, de voorliggende concept overeenkomst, de oS, etc). RM zou moeten evolueren in de loop van de fasen van het project, daarbij begint het in de tenderfase en de volgende fasen. Kansen en bedreigingen, hoe zie ik dat nu? Het ontwerp wordt steeds duidelijker, daarbij neemt de complexiteit en intensiteit toe. Steeds meer mensen zijn betrokken bij het project en het beslissingsproces, wat leidt tot meer detail. RM moet er dan in toenemende mate voor zorgen dat het een beheerst proces blijft. Het gaat dus om de balans tussen kansen en bedreigingen zien in het begin, waarbij met de toenemende teamomvang en specialismen de scope steeds breder wordt, en beheersing van het proces. In dit proces gaat het om het om een beslistraject gericht op het maken van het winnende aanbod waarin de maximale creativiteit is verankerd.

Hoe zou RM uitgevoerd moeten worden om deze balans te realiseren? Daarbij is het ook de vraag of RM de taak is van één persoon of alle teamgenoten? Persoonlijk gezien zou er één iemand procesmatig verantwoordelijk moeten zijn, maar inhoudelijk is het de taak voor iedereen om actief met RM bezig te zijn. Bij het begin van het tenderfase moeten de keyspelers zorgen voor deze invulling. Deze keyspelers zijn o.a. de tendermanager, ontwerpmanager/architect, financieel manager, bouwkundige en misschien nog wel een LCC-deskundige. Eigenlijk wil je van een DBFMO alle disciplines aan tafel hebben, D&B, M&O en F. Maar iedere verantwoordelijke van deze disciplines moet RM voeren. Met deze mentaliteit is er geen risicomanager nodig om het team scherp te houden, maar dan moet RM wel een onderdeel van het denken zijn. Zodra de complexiteit toeneemt en het team dan gegroeid is tot bijvoorbeeld 20 tot 30 mensen, heeft nog steeds iedereen zijn verantwoordelijkheid maar is het wel goed om een sturende procesverantwoordelijke in te schakelen. Deze verantwoordelijke moet dan niet ‘op de stoel gaan zitten’. Iedereen in het team moet zijn eigen verantwoordelijkheid blijven dragen en niet gaan afschuiven op de risicomanager. Waar ‘iedereen’ RM nu ziet als een ballast, een meervoudige A3 lijst met 20 kolomen die niet uitnodigt om mee te werken, zou het juist een interessant moeten zijn om er mee te werken. In plaats van complexe, grote lijsten, zou de tool zou er voor moeten zorgen dat het proces behapbaar wordt. De bijbehorende tool moet er voor zorgen dat alle betrokken mensen met hun affiniteit met RM overweg kunnen en gaan.

De volgende vraag is dan hoe de risico’s met hun oorzaken, gevolgen, classificaties en mitigerende maatregelen verwerkt zitten in het proces. Momenteel doet niemand iets met die maatregelen, er worden bijvoorbeeld geen andere ontwerpafwegingen gemaakt. RM zou een dialoog moeten worden om, doormiddel van bijvoorbeeld SE, ontwerpafwegingen te maken. Door RM zo te benaderen volgen er totaal andere gesprekken dan wanneer het neer komt op het invullen van een tabel. Iedereen denkt ‘Ojee een tabel, hoe kom ik er vanaf?’. Het is nu een kwestie van ‘moeten’, alsof je jouw belastingpapieren invult; zo snel mogelijk invullen en dan weer leuke dingen. De evaluerende rol van RM, de iteratieslag in het proces, ontbreekt. En wat betekenen die getallen nu precies (met name ook hoe eenduidig zijn deze (is er sprake van appels en appels / hoe is verder de wegingsystematiek vormgegeven)? Wat zeggen die uitkomsten nu?

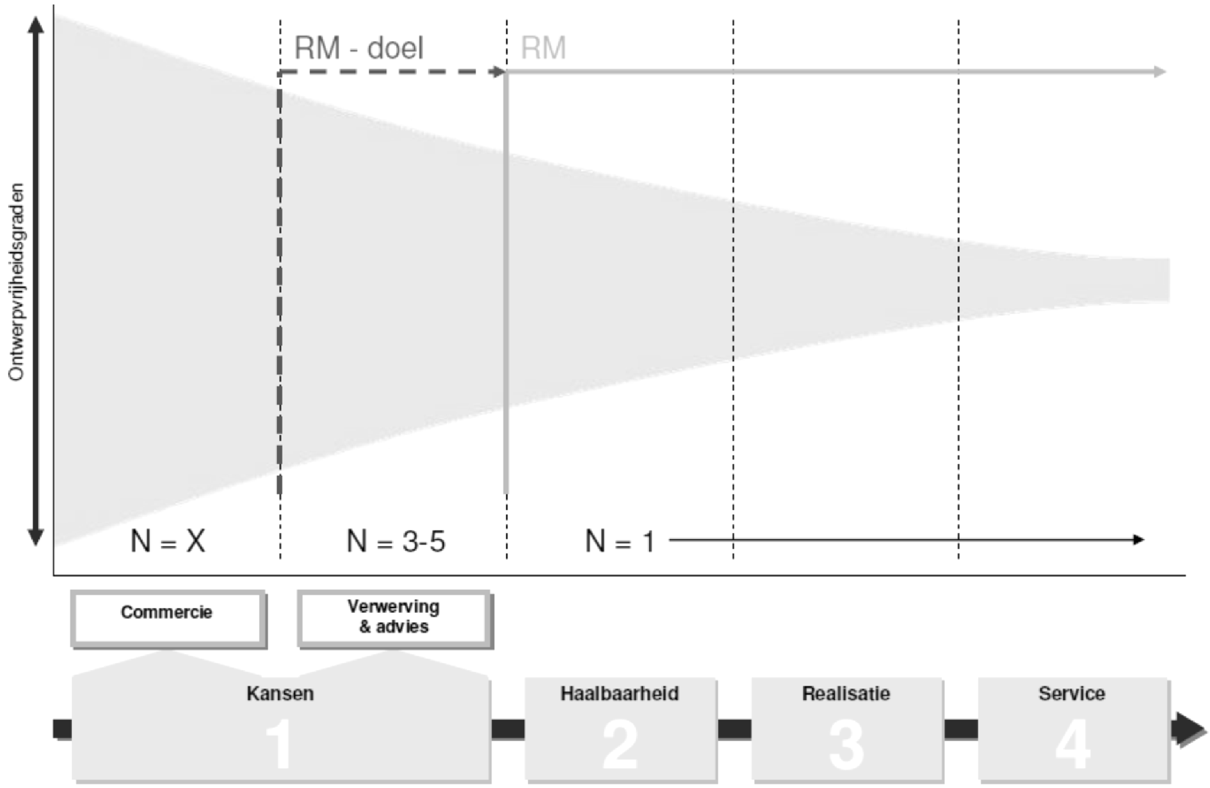
Hoe worden de mogelijke risico's van de juridische en financiële aspecten meegenomen in het RM proces? Bijvoorbeeld de werking met derden.
Kansen/mogelijkheden begint bij het ontleden van een aanbestedingseigenaar, een EMVI vertelt mij 'hoe kan ik winnen?'. Op basis van de analyse van die EMVI worden biedingstrategieën of scenario's ontwikkeld. Daarbij gaat het om kwaliteit, prijs en overeenkomsten. Dat laatst vraagt dus ook om een contractanalyse. Maar ook een analyse van de betalingsmechanismen. Deze is nodig vanwege nieuwe betaalstructuren, zoals de beschikbaarheidvergoeding en prestatiekortingen, met alle risico's van dien.

Het aantal beperkingen geeft ook het kortingregime mee voor welk ontwerp je nou wel of niet wil maken. Die beslissingen kunnen niet alleen worden gemaakt en vereisen interactie met utiliteit, wegen of een andere uitvoerende partij. Specifieke kennis van bijvoorbeeld materialen is nodig om tot een ontwerp te komen dat voldoet aan de EMVI eis(en). De rol van PPP is het vertalen van de ontwerpoverwegingen naar financiële consequenties. Door deze te plaatsen in een financieel model kan worden aangetoond wat ontwerpoverwegingen financieel met zich meebrengen, zeker met een levensduur van bijvoorbeeld 25 jaar.

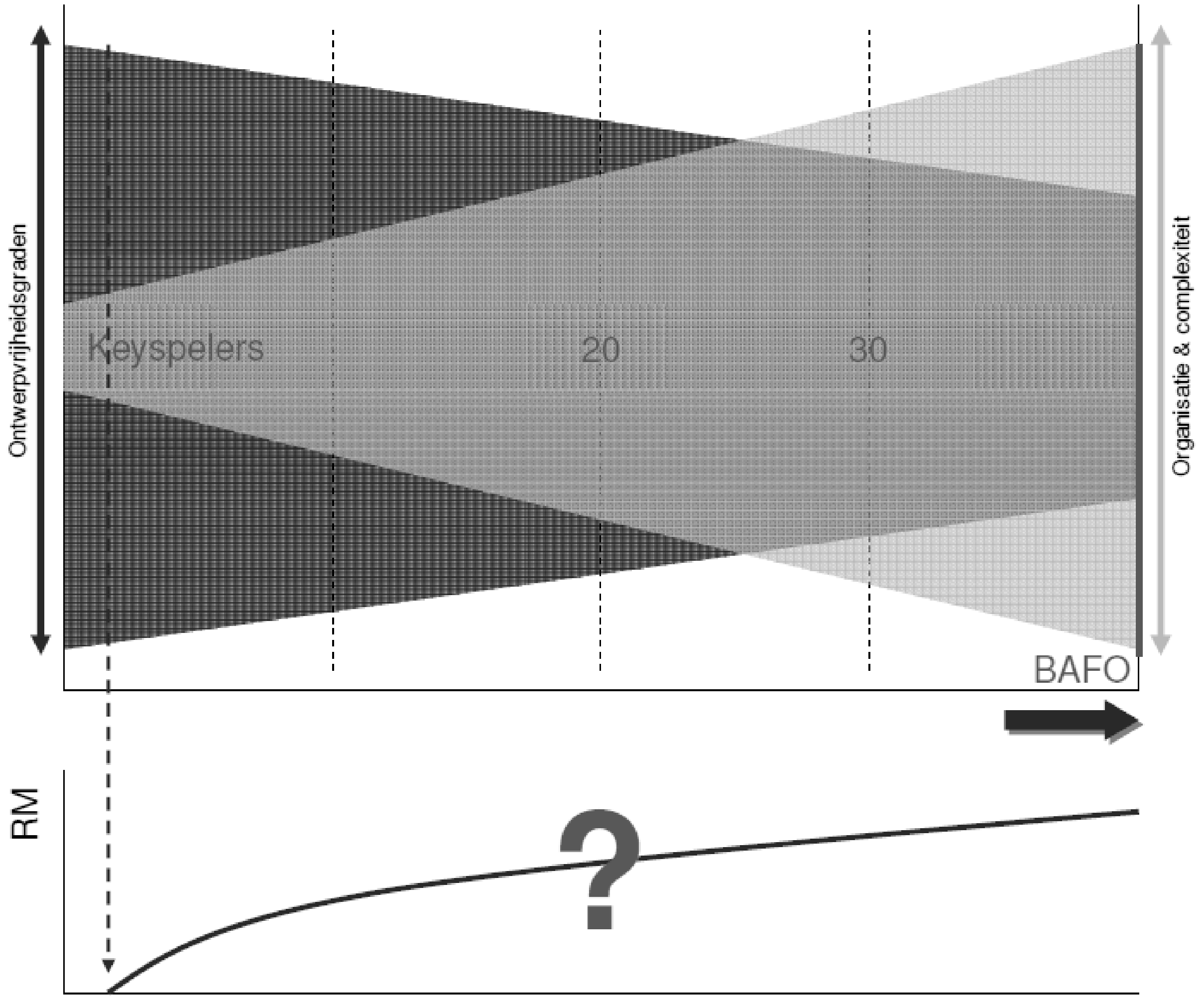
Hoe ervaren jullie de methoden van utiliteit en wegen?
RM bij utiliteit is momenteel een invuloefening, er is wel een systematiek echter deze wordt teveel als een verplicht invuloefening gezoen en er is geen/amper visie wanneer het in het proces aan de orde moet komen en er is amper eigenaarschap. Uit ervaring komt het traditioneel laat aan de orde. Er is geen gewoonte om er vanaf het begin mee aan de slag te gaan. Daarnaast staat er ook niet duidelijk in de tenderstrategie opgenomen wat RM nou precies inhoudt en wanneer het in het proces wordt toegepast. De rol van RM zou terug moeten komen in de tenderstrategie. Welke rol heeft RM nou in het bepalen van de biedingstrategie? En vervolgens in het uitvoeren van de biedingstrategie, misschien moet deze wel worden bijgestuurd. Deze interactie ontbreekt volledig momenteel. De methodiek maakt dan nog niet zoveel uit, dat zou een ondersteunend element moeten zijn van deze interactie. Eerst schot zien te krijgen op het proces van acquisitie tot realisatie of onderhoud en wat is nu precies de rol van RM in dat proces. Dit kan vervolgens ook worden omgezet naar Blok 2 etc. Voor de daadwerkelijke uitvoering kan er dan gekeken worden naar de bouwplanningen bijvoorbeeld. Van VO, via DO naar UO.

Hoe gaan jullie dan met de risico's in de fasen na oplevering aangezien er binnen Heijmans en eigenlijk de gehele markt hier nog relatief weinig van bekend is?
In eerste instantie identificeren en verder blijven dat gewoon onzekerheden. Als er bijvoorbeeld een nieuw gevelsysteem wordt toegepast dan is er natuurlijk nog niet bekend hoe het zich houdt over de komende 25 jaar. Daar gaat het om goeddoordachte keuzes maken en weten waar de mogelijke risico's zitten. Er kan specifiek gestuurd worden op het beheren van de mogelijke risico's. Door een actieve houding op dit risicobeheer kan manifestatie voor worden gebleven, het is geen 'proven technology'. Dit dan ook meenemen in het risicodossier door ze te benoemen en mitigerende maatregelen voor je risico reserveren. Er moet nog steeds worden nagedacht over je mitigerende pakket over 25 jaar.

Maar daar zit nog wel een bepaalde naïviteit in over die 25 jaren door opmerkingen zoals 'dat risico hebben we weggelegd'. Maar waar is dat dan weggelegd en bij wie? Als bijvoorbeeld een onderaannemer failliet gaat, dan komt het risico wel weer bij Heijmans terecht. Goed RM zou daar doorheen moeten prikken door naast onderhoudsrisico's ook vervolgrisico's te analyseren.



Figuur 1: Het aantal teams per project fase en de ontwikkelingsvrijheidsgraden in de loop van het proces



Figuur 2: De omvang van de organisatie uitgezet tegen de ontwerpvrijheidsgraden in de loop van het process, vraag is waar en in welke mate risicomanagement toegepast dient te worden

Appendix B.3
Interview Yvette Naaijkens (Dutch), Systems Engineering , taken on 12-10-2012

Gesprek gevoerd om wederzijds inzicht te krijgen in de werkzaamheden. Gedurende het gesprek zijn er omtrent de onderwerpen een aantal aandachtspunten aan bod gekomen, hieronder een korte omschrijving van de bevindingen.

Huidige proces
In huidige processen/projecten wordt wel aan het volledige team gevraagd om het RMO in te vullen, er heerst echter een drempel waardoor invulling of achterwege blijft of op het laatste moment (2-3 dagen voor de deadline) plaats vindt. Momenteel komt de verantwoording en de bijkomende druk van o.a. het contractmanagement en risicomanagement bij de tendermanager te liggen, naast de verantwoording als teammanager. Door het ontbreken van de gedeelde verantwoording, komt het teamaspect niet van de grond. De tendermanager zal daarom grotendeels moeten vertrouwen op de eigen kennis en ervaringen om het RMO in te vullen. Daarbij kan de tendermanager theoretisch terugvallen op de ervaring van risicomanagers onder de mom van het vier-ogen principe, deze hebben echter hun eigen verantwoordingen en bezigheden waardoor de tendermanager uiteindelijk toch op zichzelf is aangewezen.

Traceerbaarheid door documentatie
Om het proces te verbeteren, gezamenlijk met de spreiding van de verantwoording, moet er meer controle worden gecreëerd. Door 'in control' te zijn, ontstaat er een betere toezicht op alle elementen, personen en acties die op het project betrekking hebben. Daarbij is ook het bijhouden van de ondernomen acties aangaande deze controle van belang. Het sturen op procesdocumenten en het gebruik daarvan, vergroot de traceerbaarheid. De basis voor de documentatie moet continu aanwezig zijn in het proces in plaats van een statische, eenmalige invuloefening.

Bij geïntegreerde contracten worden in het begin alle eisen gedocumenteerd van alle fasen die zijn opgenomen in het contract. Door deze documentatie zijn alle gestelde eisen traceerbaar, ook in de exploitatie. Door risicomanagement op vergelijkbare wijze te documenteren kan er op ieder moment in het proces getraceerd worden welke beheersmaatregelen genomen zijn om risico's te beperken. SE is een geschikte mogelijkheid om deze documentatie te verwezenlijken en beheersmaatregelen te koppelen aan de eisen. In eerste instantie wordt bij SE een WBS en SBS opgezet om de eisen te vertalen. Het RMO dient gekoppeld te zijn aan deze eisen, daarom worden de risico's toebedeeld op elementniveau binnen de SE structuur.

Implementatie binnen de divisies.
Binnen de divisie infrastructuur wordt er al over een langere periode gebruik gemaakt van SE. Daarbij is de Systems Engineer tevens de Risicomanager vanwege het totale overzicht dat hij/zij heeft over alle elementen van het systeem. Deze Systems engineer/risicomanager maakt onderdeel uit van 'project support', een team ingericht om ondersteuning leveren in project teams door o.a. risico- en contractmanagers (juristen) te leveren. Dit neemt de eerdergenoemde druk weg bij de tendermanager.

Bij implementatie van SE binnen U-bouw is de vraag waar het zou moeten landen en wie de verantwoordelijkheid komt te liggen. Daarbij is het van belang om te kijken hoe het principe leeft in de volgende blokken en welke stappen nodig zijn indien dat niet het geval is. Daarbij is terugkoppeling vanuit alle blokken nodig om feedback te genereren. Deze terugkoppeling ontstaat door het ontwikkelen van communicatie over de linie. In alle fasen van het project moet de gedocumenteerde informatie beschikbaar zijn, gezamenlijk met de mogelijkheid om deze up te daten en feedback te leveren.

Bij implementatie is het uiteindelijke streven een toepassing van de methode over de gehele linie (communicatie is hier een onderdeel van). Om deze implementatie te ondersteunen, is standaardisatie van de , bestaande/SE, methode en de bijkomende elementen van belang. Daarbij zou iedereen moeten werken in één document, dit verhoogt de efficiëntie (alle informatie is direct verzameld) en centraal te vinden voor alle betrokken teamleden.

Appendix B.4
Interview Kenzo Oijevaar (Dutch), HIGP, taken on 19-11-2012

Welke methode wordt er binnen HIGP gehanteerd voor RM (risicomanagement)?
HIGP hanteert een eigen RMO, gebaseerd op de RISMAN methode, waarin onderscheid wordt gemaakt tussen een tender- en een uitvoeringsgedeelte. Dit is ontstaan omdat RM in eerste instantie is opgepakt vanuit de tenderfase. Momenteel zijn wij binnen HIGP wel bezig met een grote vernieuwingsslag. De grote lijnen van deze vernieuwing staan, het vraagstuk is nu hoe de vernieuwing binnen de organisatie moet wordt geplaatst.

De huidige methode draait reeds Monte Carlo analyse. De vernieuwing richt op de verbetering van de identificatie van zowel risico's (bedreigingen) als kansen. Daarbij wordt ook gekeken naar de invloed van identificatie uitkomst op de (ontwerp)keuzes: 'is de huidige situatie toereikend of moet een beheersmaatregel worden toegepast om tot een verbetering te komen?' Door te kijken of het loont om de beheersmaatregel uit te voeren kan de invloed SMART bepaald worden. In het geval van een kans is het vraagstuk of de gevraagde investering zo hoog dat de kans zichzelf ongedaan maakt. Deze keuzes wil je beter kunnen onderbouwen op basis van bijvoorbeeld ervaringscijfers of statistiek.

Uiteindelijk moet het mogelijk zijn om te monitoren door het project heen: Wat was de omvang van je risicobudget, welke investeringen waren nodig voor de beheersmaatregelen, hoe hoog was je restrisico en hoe verhouden beheersmaatregelen c.q. correctieve beheersmaatregelen zich t.o.v. je risicopot?

Is het aan te raden om bij kwalificatie een top 5 of 10 te selecteren alvorens deze te kwantificeren?
Waarom leg je de focus op de top 5? Is de zesde niet van belang? Vanuit de opdrachtgevers wordt er vaak gevraagd om een top 10. De huidige ontwikkeling binnen HIGP gaat zich echter meer richten op ketens door RM benaderen doormiddel van ketenbenadering. Gevolgen c.q. beheersmaatregelen zouden best van toepassing kunnen zijn op meerdere kansen of bedreigingen, terwijl deze momenteel vaak nog dubbel worden gerekend. In de huidige tool krijgt iedere rij in de tabel een aparte beheersmaatregel. Als deze vervolgens worden bekeken en gekwantificeerd, dan kan het zo zijn dat een beheersmaatregel meerdere keer geregeld moet worden. Waarom wordt deze maatregel dan niet in één keer uitgevoerd? Echter kan zo'n beheersmaatregel bijvoorbeeld locatie gebonden zijn, automatisch resulterend in een gefragmenteerd proces. Bij het ontwikkelen van de maatregelen kun je dan ook niet generiek, maar wel bewust te werk gaan. Het opzetten van een risicoketen biedt de mogelijkheid om te kijken welke factoren zich in dezelfde keten bevinden en elkaar derhalve beïnvloeden. Het toekennen van prioriteit gebeurt dan op basis van ketens in plaats van losse risico's. Een gedachte is dat ieder oorzaak of gevolg in de keten als los risico gezien zou kunnen worden.

In de huidige ontwikkeling wordt het nog geen volledige integrale keten, maar een logisch opvolging van factoren met als kernvraag: 'waar zit nou eigenlijk echt de crux?' Dat helpt je ook om beter te snappen waar de focus gelegd zou moeten worden. Over de tijd treden verschillende risico's op die elkaar (mogelijk) beïnvloeden, resulteerde in ketens. Wat je dan feitelijk zou willen weten is wat die risico's en factoren inhouden en op welke de focus zouden moeten liggen. Anderzijds, als je gaat beheersen, welk risico of factor in de keten moet dan beheerst c.q. gecorrigeerd worden? Waar heeft de beheersing het meeste effect? Door statisch de kans door te rekenen in de keten en dit inzichtelijk te maken doormiddel van een tornado diagram, kan je aantonen waar de meest invloedrijke elementen zich in de keten bevinden.

Zodra een overzicht van de risico's is ontwikkeld, krijgen al deze risico's een eigen curve (normaal, binaire etc.). Deze curven worden gecombineerd met als resultaat het uiteindelijke Monte Carlo profiel. Dat profiel wordt getoond in relatie tot een nulwaarde. Deze nulwaarde is de verwachte waarde gebaseerd op input van je verwachte kansen (waarschijnlijkheid) en gevolgen. Dit wordt vervolgens uitgebreid met een worst case, worst worst case, best case en best best case scenario. Daar zet je vervolgens op uit wat je spreiding is in verhouding tot je verwachte risicopot. In eerste instanties zal die risicopot puur gebaseerd zijn op een situatie zonder beheersmaatregelen en investeringswaarden van de collectieve maatregelen dan toegepast gaan worden. De spreiding van de worst case en best case t.o.v. de nulwaarde geeft aan of beheersing nodig is. Vanuit de initiële situatie ga je een iteratief proces door waarin je het risicoprofiel van het gehele project binnen een bepaalde spreiding probeert te krijgen. De acceptatie van het risicoprofiel in je project wordt gezamenlijk bepaalt en vereist derhalve ondernemerschap. Misschien wil je standaard 90% zekerheid hebben of zet je juist risicovoller in op een project? De verwachte waarden voor je risico's blijven dan hetzelfde, de acceptatie verschuift met de een hoger of lager budget van dien. Het streven is niet meer specifieke beheersmaatregelen, maar het sturen op een vooraf gedefinieerd risicoprofiel. De mate van acceptatie is dan te bepalen door de directie. Wat je dan dus wil is het uit elkaar trekken van het feitelijke risicodossier en je ondernemerschap. Tegelijkertijd moeten ze beide inzichtelijk worden gemaakt om de traceerbaarheid en meetbaarheid te vergroten.

Deze genoemde processen vinden allemaal plaats in de tenderfase. Daarna kom je in de cyclus terecht waarin het project gaat lopen en mogelijk veranderingen optreden, maar de initiële keuzen liggen in de tender. In het volgende proces ga je monitoren, bijvoorbeeld of de beheersmaatregelen up-to-date zijn, of de gekozen maatregelen nog wel de juiste zijn en hoeveel invloed hebben veranderingen op de juistheid van je gehele systeem? Vanuit het systeem ga je vervolgens redenen waar de moeilijkheden of de kansen, gecombineerd de onzekerheden, zitten.

Is dat proces dan gebaseerd op de RISMAN methode?
Nee, dat is juist ook de hele discussie, zelf ben ik er geen voorstander van om je spreiding van je risico te bepalen aan de hand van de RISMAN methode. RISMAN zorgt voor een spreiding op basis van bandbreedtes. Je zou juist uniek per risico moeten weten welke curve er bij hoort (kanttekening daarbij is de vraag of de organisatie dat aan kan). Dit is echter alleen mogelijk als er goede gegevens voor handen zijn en daar zit een belangrijk vraagstuk. Is je team instaat om de waarden goed in te schatten en daarover tot consensus te komen? Ook de draagkracht van de organisatie is daarbij van belang: Hoe moet deze worden opgeleid om dat te kunnen? Dit omvat alle niveaus, tot en met bestuursniveau; zij moeten begrijpen hoe ze het proces kunnen sturen aan de hand van de spreidingsinformatie doormiddel van (correctieve) beheersmaatregelen. Ook het bijstellen van hun verwachtingen is van belang, anders heeft het weinig toegevoegde waarde om alle

informatie in een rapport op te nemen. Andersom moet een deskundige ook weten wat een door hem/haar ontwikkelde beheersmaatregel voor een invloed heeft op de andere elementen in de keten; de beste beheersmaatregel voor een specifiek risico, kan te zwaar zijn in vergelijking met de focus in de keten. Het aansturen van het gehele proces omtrent de ontwikkeling en toepassen van de kennis is een belangrijke taak voor de risicomanager.

Wat voor rol een heeft de risicomanager daar dan in?
Momenteel is het zo dat de risicomanager ook daadwerkelijk de risico's beheert, hij/zij is degene die de expertise haalt bij 'plekken' en zorgt dat daar iets uit voortkomt. Onderwerpen waar specifieke vragen over zijn kan hij/zij vervolgens weer voorleggen aan de juiste deskundigen, bijvoorbeeld een tendermanager of projectleider afhankelijk van de fase waarin het project verkeerd. Tijdens de tenderfase zal hij/zij proberen alle informatie te achterhalen door risicosessie te initiëren om uiteindelijk tot een slotconclusie te komen, deze wordt weer aan de tendermanager voorgelegd. Dit proces is momenteel nog niet echt iteratief en dat is in de tender ook lastig, de tijd is beperkt; kan het dan ook wel iteratief? Wat je eigenlijk zou willen is de beste keuzes maken op basis van je risicoprofiel en door uit te spreken waar je met elkaar naar toe wil m.b.t. de acceptatie. Daar moet je eerst een visie over hebben. Voor het ontwikkelen van een visie moet je ook eerst je systeem goed in kaart gebracht hebben voordat je kan bepalen waar je de beheersmaatregelen gaat toepassen en pas dan kunnen er iteratieve ontwerpslagen gemaakt worden.

Hoe kunnen de curven worden opgesteld voor de spreiding van specifieke risico's?
Om dit goed te kunnen (dit kan momenteel nog niet) heb je eerst goede en betrouwbare gegevens nodig uit het verleden, daarmee ontstaat een kennis- en ervaringdatabase. Het aanleggen van een database is echter niet eenvoudig aangezien niet voorzien kan worden in kant en klare informatie; bouwprojecten en logischerwijs dan ook de situaties waar de beheersmaatregelen op los worden gelaten, zijn per definitie uniek van aard. Dus hoe meer -locatiegebonden- data, hoe beter. Dit vraagt om voorwaarden die aan de database gesteld kunnen worden. Het is daarbij een goede vraag hoe een dergelijke database moet worden ingericht. Er is al een start gemaakt door duidelijke documentatie, maar voorlopig gaat het vooralsnog om het verzamelen van de informatie. Anderzijds heb je natuurlijk de experts en hun specifieke kennis nodig om hun inbreng te leveren, samen met de statistiek die bij derden buiten je team en buiten je organisatie ligt. Dit kan een externe database of expert zijn, maar deze spiegel is wel nodig; naar buiten treden gebeurt vooralsnog veel te weinig. Het onderbouwd brengen van cijfers is dus afhankelijk van interne database, een team dat in staat is om input en feedback te leveren en externe partijen voor additionele informatie of spiegeling. Subjectieve aannames moeten voorkomen worden.

Momenteel wordt informatie verzameld in een lopend Lean SixSigma project om inzichtelijk te krijgen hoe er in een project wordt omgegaan met beheersmaatregelen over bijvoorbeeld tijd. In relatics wordt daarvoor nu naast de RMO ook een management dashboard gemaakt dat o.a. aangeeft welke beheersmaatregelen zijn uitgevoerd, welke nog open staan en alle maatregelen binnen de gestelde deadline zijn gerealiseerd. Dit dashboard geeft een snel overzicht van het proces en kan met één druk op de knop worden geprint. Data goed achterhalen blijkt momenteel namelijk lastig voor een manager. Hij heeft geen tijd om het hele systeem door te lopen, een dashboard ondervangt dit probleem.

Hoe gaat het in de overdracht, wordt er gewoon met het systeem gewerkt?
Ook in de uitvoering wordt er gewoon met relatics gewerkt, het is zelfs de bron van de data. Bij Utiliteit zit het allemaal net even anders. Daar zijn ze natuurlijk pas net begonnen met relatics, er zijn nog geen complete risicodossiers in relatics. Feitelijk is het niet belangrijk waar je het risicodossier in bijhoudt. Zolang je dossier maar op orde is, maakt het systeem niet zo veel uit. Het is het wel van belang dat je de risico's, kansen, beheersmaatregelen, etc. wel qua informatie kan koppelen aan alle programma´s die dat nodig hebben. Verder is het van belang dat iedereen het dossier ten allen tijden in moeten kunnen zien.

Een ander punt is dat de concreetheid van bedreigingen en kansen vaak op een abstract niveau zit en vraagt dus om verder concretiseren van karakteristieken. In de tenderfase is het lastig voor de betrokken teamleden om de risico's goed te formuleren. Ze onderkennen een probleem, maar het bedenken van de precieze omschrijving blijkt vaak lastig te zijn; men blijft in het abstracte niveau hangen.

Hoe wordt dit probleem punt dan benaderd in het huidige proces?
Momenteel kunnen we vaak nog niet aan genoeg ervaringscijfers komen om die curven goed op te stellen. Daarom nemen we nu vaak een waarde met een zeker onnauwkeurigheid. Deze waarden zijn ook risicospecifiek, de ketenbenadering is nog in ontwikkeling. In de teams zelf werkt men proactief met bedreigingen en kansen, deze worden ook proactief ingevuld in de documentatie systemen vanwaar vervolgens zo rapporten kunnen worden uitgedraaid. Wat nu opvalt is dat RISMAN er totaal niet in verwerkt is. Alles is in geld uitgedrukt en in kans keer gevolg (ook in geld); alles wordt naar geld teruggeredeneerd, tijd is daarnaast ook een belangrijke factor. Maar hoe worden nou zaken zoals imago uitgedrukt in tijd of geld? Dat zijn relevante vragen waar nu naar gekeken wordt. RISMAN kan hier overigens wel goed voor gebruikt worden om een basis indruk te krijgen. Maar het is raar om geld en tijd op dezelfde manier te waarderen als imago, want imago is uiteindelijk een probleem dat zich uit in tijd of geld. RISMAN zegt eigenlijk: we hebben een pot geld, en dat geld wordt gebuikt om collectieve maatregelen te betalen. RISMAN kijkt dus niet vanuit de keten maar kijkt vanuit de eerste linie achter een situatie om concrete maatregelen aan te leveren. Maar op de lange termijn reken je uiteindelijk niet mee wat bijvoorbeeld veiligheid of kwaliteit kost qua geld. Het zorgt voor een score die de omvang van het risico weergeeft, maar dan is het nog niet omgezet naar de feitelijke kosten en planning. Dat laatste is wel het doel. Vanwege dat doel draaien we nu de Monte Carlo analyse over tijd en geld, hoewel dat alleen wordt toegepast op grotere project. RISMAN werkt dus wel op het eigen niveau, maar zodra er meer diepgang/detaillering gevraagd wordt, wil je alles uitdrukken in tijd en geld.

Hoe wordt relatics daar in toegepast?
Relatics is niets meer dan een database. Elementen worden vanuit SE gekoppeld worden aan activiteiten of objecten. Zodra je dan dat element opent, staat daar direct het gekoppelde risico bij. Bij het verifiëren van een bepaalde eis kan het zijn dat het element voor een te grote bedreiging zorgt en de eis dus eerst extra aandacht vraagt.

Het invoeren van risico's wordt gedaan via vaste procedures door personen binnen een team. Degene die het risico invult, zorgt ook voor de bijkomende waarden voor de waarschijnlijkheid, kosten, tijd etc. via RISMAN of Monte Carlo. In de tender gaat de documentatie vervolgens op een gegeven moment op slot en mag niemand daar meer in werken. Alleen de risicomanager mag dan zorgen voor de laatste fine tuning, anders dan kunnen mensen dingen blijven aanpassen. Dat zou er voor kunnen zorgen dat besluitvorming gebeurt op basis van 'verouderde' informatie doordat iemand achteraf aanpassing heeft gemaakt. In het geval van grote wijzigingen, dan kunnen deze door de groep plenair besproken en doorgevoerd worden. Bij de initiële inventarisatie is echter iedereen betrokken en heeft iedereen toestemming om risico's toe te voegen aan het dossier. De ene is daarin proactiever dan de ander, het is aan de risicomanager om dat proces te beheersen en wel alle risico's naar boven te halen.

Heb je dan niet het idee dat het voor sommigen dan een verplichte invuloefening wordt?
Nee, dat hangt er vanaf hoe je het brengt. Ik zet risicosessies op met logische groepen, zo zorg ik ervoor dat het geen te globale sessie wordt en bij disciplines blijft. Ten tweede ga ik kansen en bedreigingen doornemen: ik wijs op tekeningen een plek aan en vraag wat daar nou de mogelijke problemen of mogelijkheden zijn. Als je dat dan ook vanuit problemen of mogelijkheden benadert en niet risico's, dan gaan personen meer denken in dingen die mis kunnen gaan of waar verbetermogelijkheden liggen. Vervolgens ga je er met die groep meteen doordenken over invullingen voor verbetering. Vaak komen daar acties uit voort. Mocht iets nog niet duidelijk zijn, dan kun je daarin doorvragen of kan de probleemeigenaar de factoren verder uit gaan zoeken. Het moet een gesprek zijn in plaats eenrichtingsverkeer.

Zodra alle risico's in kaart zijn gebracht, gaan jullie dan uit van selecties of prioriteitenlijsten?
Vroeger was het de top 10 op basis van RISMAN, nu zeggen we: 'alles waar geld aan zit is belangrijk'. Je moet gewoon alle bedragen weten en niet alleen de bovenste tien, anders is je risicopot nooit toereikend. Ook wil je weten welke beheersmaatregelen er allemaal preventief moeten worden toegepast. Doormiddel van een volledige lijst kan er ook geverifieerd worden of alle calculaties en berekeningen volledig zijn doorgevoerd. De directie dient ook het bedrag voor het totale restrisico te weten, dan is een top tien niet toereikend. En aan de andere kant, risico's die niet uit te drukken zijn in tijd of geld, daar kunnen we niets mee, kwantificeren is dan in de tender niet mogelijk. We kunnen wel een plan schrijven over hoe het risico beheert moet worden beheert; concretiseren is dan vaak niet het probleem, maar het achterhalen wel.

Werken jullie bij het achterhalen nog met categorieën?
Je kan wel sturen op risicoaspecten. Waar ik het vooral voor gebruik is om mensen buiten hun expertise te laten denken; bijna iedereen hier is een techneut, vergeten we dan niet de politiek? Het is een handvat om te sturen dat we breder gaan denken dan dat we standaard doen, het is een tool. Als dan wordt aangegeven dat een ander (niet technisch) aspect daadwerkelijk geen probleem is, dan worden er voor dat aspect ook geen risico's opgenomen. Daar houdt het ook bij op, meer hoef je niet te doen met die categorieën. Je moet uiteindelijk er wel naar streven dat je alles geïnventariseerd hebt, al dan niet expliciet.

Wat voornamelijk belangrijk is om te doen is focussen op kansen. Momenteel is er te weinig focus op kansen, mensen denken veel te veel in problemen. In mijn optiek zijn we alleen maar bezig met onzekerheden, het enige verschil is of we het nu of later in de planning gaan beheersen. Een onzekerheid kan positief of negatief uitvallen; positief is een kans, negatief is een risico (bedreiging). In alle gevallen gaat het dan ook om een onzekerheid en is de vraag of je die als kans of bedreiging benadert; op welke manier wordt er in de tender geld begroot? Is dat vooraf om een beheersmaatregel te bewerkstelligen, of gaan we het risico lopen?

In de ideale wereld zijn System Engineers en risicomanagers overbodig, iedereen houdt zich met RM bezig om er gezamenlijk uit te komen; het is alleen geen ideale wereld. Je hebt mensen nodig die motiveren om met RM bezig te gaan. Dat zou een taak van de procesmanager kunnen zijn, maar uit onze ervaring blijkt dat die daar geen tijd voor heeft en kun je het beter overlaten aan iemand anders. Het is wel een belangrijk procesonderdeel, want de informatie die er uit volgt moeten de kernteamleden en de stuurgroepleden gebruiken als sturingsinformatie. Het is dan dus wel van belang dat er iemand proactief bij mensen langs gaat en deze informatie kan uitdragen. Het functioneert niet als iemand die dus nog nooit als risicomanager heeft gewerkt wel die rol moet gaan dragen in een project. Het is misschien wel een opties om een dergelijk iemand dan ook tegelijkertijd als risicomanager op te leiden, anderzijds vraagt dat dan wel weer om een organisatie die voor die opleiding kan zorgen.

Bij HIGP is het zo dat de tendermanager geen tijd heeft om als risicomanager te fungeren; hij wil wel mee beslissen over grote risico’s en hij wordt ook vaak betrokken bij risicosessies, maar hij is er om het proces te sturen om discussie op te lossen. Hij moet verder wel op de hoogte zijn van bedreigingen of kansen, maar het feitelijke proces daar omheen zou niet de verantwoordelijkheid moeten zijn van de tendermanager (bij een groot project). Bij een klein project zou dat wel een optie kunnen zijn, maar dan is het misschien logischer om de projectmanager verantwoordelijk te maken. Met de nieuwe blokken binnen utiliteit is het misschien verstandig om inzichtelijk te maken waar de verantwoordelijkheden momenteel liggen en vervolgens waar deze zou moeten liggen m.b.t. RM.

Appendix B.5
Interview Harwil de Jonge (Dutch), Heijmans Vastgoed, taken on 12-09-2012

Hoe wordt binnen Heijmans Vastgoed omgegaan met risicomanagement, de methode en het achterliggende model?
Het model is gemaakt voor het GZG, een locatie in Den Bosch en is opgezet met behulp management trainees. Naar wordt er binnen het gebiedsontwikkeling bedrijf gebruik gemaakt van de fase verslagstructuur. In het proces heb je een aantal fase die doorlopen moeten worden, opstartfase, pve-fase etc. Per doorlopen fase wordt een fasedocument opgesteld waarin wordt verteld wat er in die bewuste fase gedaan is, wat het doel is van de volgende fase, wat de risico's, kansen etc zijn op verschillende vlakken en je vraagt budget aan om de volgende fase in te gaan. Elkaar wordt daarmee één stap van het proces doorlopen en dat wordt geaccordeerd door de verantwoordelijken; het doorlopen van de verschillende fasen wordt continue op deze manier stapsgewijs ingericht.

Hoe gaan jullie in die fasedocumenten en het achterliggende proces om met het identificeren van kansen en bedreigingen?
Om die rede hebben we voor het GZG een opzet gemaakt om meer grip op dat proces te krijgen zonder het direct uitgebreider te maken. Want wat in de faseverslagen wordt het wel benoemd, maar daarnaast moet je ook kunnen monitoren en kijken of een risico voorkomen kan worden. Wat voor een acties zijn er nou nodig om een risico te elimineren. Bij HIGP zijn ze daar al veel verder in dan bij Vastgoed, dit verschil is ook gebleken uit een samenwerkingsverband tussen vastgoed en HIGP voor de tender van de A2 Maastricht. Hoewel het om andere risico's gaat, is ook het management daarvan van een hele andere orde. Het draait vooral om het inzichtelijk maken van de risico's, de consequenties en doormiddel van welke acties een risico geëlimineerd kan worden. Daar kun je uiteindelijk financiële of andere consequenties aanhangen. Dat was ook het doel van het GZG terrein om een opzet te maken waarmee een vergelijkbaar proces werkbaar is binnen vastgoed. Vanuit allerlei verschillende thema's die je tegenkomt zoals ruimtelijke ordening, gebouwniveau of eigenlijk verschillende schaalniveaus, is het goed om met het team na te denken over de te benoemen risico's. Bij het benoemen van die risico's kan je hele lijsten opstellen. Op deze lijsten kun je acties opstellen en wegstrepen. Misschien moet je juist een proces anders inzetten om een risico te elimineren. Door het opzetten van zo'n benadering kom je er achter dat eigenlijk veel van deze acties al uitgevoerd worden, maar dan rest wel de vraag of die acties structureel worden uitgevoerd of omdat ze standaard worden gedaan; het is bekend welke risico's er zijn en ze worden al jarenlang op dezelfde manier geëlimineerd, het wordt daarmee een soort toeval omdat er verder ook niets wordt bijgehouden. En als je er dan juist een keer over gaat nadenken door alles et documenteren, kom je juist extra moeilijkheden tegen of risico's die later of helemaal niet benoemd zou hebben. Doormiddel van een dergelijke documentatie zou je juist beter moeten kunnen anticiperen. Risico's die juist onvermijdelijk zijn, kun je op anticiperen door een passend budget voor te reserveren. Het was meer een poging om structuur aan te brengen en ondanks de effectiviteit van de fasedocumenten ben je er dan wel op een andere manier mee bezig.

Wat voor een risico's identificeren jullie daar dan bij?
Zoals daarnet al aangegeven, zijn die verschillende gebieden van aandacht opgesteld om een breed inzicht te krijgen. Politiek moet bijvoorbeeld besluiten over bestemmingsplannen.

Vervolgens is er ook per fase onderscheid gemaakt tussen de typen en de grote van risico's. Bij de vastgoed ontwikkeling ziet dat de over de tijd het risico in het begin hoog is, maar ook de grootste invloed mogelijk is. Naarmate het proces dan vordert zal het risico maar ook de kans tot ingrijpen afnemen.

Hoe hebben jullie die aandachtsgebieden bepaald?
De gebieden zijn opgesteld in brainstormsessies en benoemd door de betrokkenen. Het hoogste niveau is daarbij de economie en de vragenstukken die daar uit voortkomen. Dit kan natuurlijk zo breed en complex worden gemaakt als nodig, maar het moet wel toepasbaar blijven voor de organisatie. En dat kan je af laten glijden naar het kleinste schaal niveau waarbij je zelf de volledige grip in handen hebt. Een voorbeeld hiervan is de risico's in het bouwproces. Omdat we die zelf doen heb je daar veel meer grip op dan de markt risico's. De laatstgenoemde zijn ook totaal anders qua impact dan wanneer er iets mis gaat in het bouwproces. Bij het opzetten van dat schema merk je ook eigenlijk dat de hele wereld risico's omvat, dus je moet het wel gericht houden op je eigen werkzaamheden.

Wat zijn jouw ervaringen bij het werken met het schema?
Mijn ervaring is dat het snel verwaterd. Iemand moet er actief mee bezig zijn, zoals dat er bij infra mensen fulltime mee bezig zijn. Als je het 'erbij' doet, dan is de kans dat het niet beheerd en dus verwaterd groot. Iemand moet verantwoordelijk zijn, of dat dan een risicomanager is of een proces- of tendermanager die verantwoordelijk op zich neemt. Het proces moet door iemand gefaciliteerd worden. Het is dan niet de taak om voor de invulling te zorgen, maar er voor te waken dat het proces niet verwaterd. Toen de trainees binnen vastgoed het overnamen van elkaar, dan ging het goed. Nu er niemand verantwoordelijk is, is het stil komen te vallen. Het heeft echt met focus te maken en gewenning om met het model te werken, beide ontbreken.

Is er wel kans om dat alsnog in het proces te verankeren?
In het proces zijn er een aantal proceszekerheden en één daarvan zijn die faseverslagen, die moet je maken om verder te gaan. En als je de wetenschap dat je zo'n document moet maken en door die analyse daar onderdeel van te maken kun je het opnemen in het proces. Momenteel is dat ook al gedaan, maar dat is niet meer dan een SWOT analyse met plussen en minnen. Die activiteit is heel minimaal en biedt ook geen uitgangspunt om te bedenken hoe je dat kan veranderen. Als je daar een ander document aan toevoegt ben je ook verplicht, vanwege de link naar het fasedocument, om daar heel concreet mee bezig te zijn.

Het document is een geschreven stuk dat wordt voorgelegd aan de ondertekenaars die na controle nog opmerkingen kunnen hebben voordat het wordt geaccordeerd. Daarbij blijft het team, afhankelijk van de fase, werkzaam in het proces. Het grote voordeel van zo'n document is dat zodra je instroomt je snel op de hoogte kan zijn van het project door het laatste en het een na laatste document door te nemen. Je weet meteen wat het project allemaal omvat en waar het staat, het is een heel handig back up element. De kracht van het document is de verplichting en dat maakt het een eenvoudig vehikel om nieuw te verplichte elementen aan te koppelen.

Je moet het ook niet te complex en uitgebreid maken. Het wordt dan niet meer ingevuld, of het wordt ingevuld maar dan kun je er ook vraagtekens bijzetten. Je kan op verschillende manieren voorkomen dat het een verplichte invuloefening wordt. Je kan een vast format aanleveren, maar ook alleen de hoofdthema's benoemen en doormiddel van een brainstorm met het team de invulling geven. En alleen dat proces van samen nadenken, ook in het begin, is al waardevoller dan het invullen van een standaard schema invullen. Als je zelf over nadenkt blijf je er ook langer mee bezig en stel je jezelf proactief op. Daar volgen dan weer discussies uit waarmee juist de dialoog wordt opengebroken.

Ook moet je ook goed naar de bedrijfsstromen kijken. Bij die samenwerking voor de A2 moesten wij vanuit de opdrachtgever mee in dat RM model. Maar in de begin fase zijn wij op een heel ander ontwerptraject bezig. Bij een gebiedsontwikkeling stel je een visie op en daar worden de elementen op ingevuld; het raamwerk is flexibeler. En je moet met je format opletten dat het zijn doel niet voorbij schiet omdat het nodeloos concreet of complex is voor het proces. Dan wordt het ook invullen omdat het moet van de klant en je punten misloopt. Het is de bedoeling dat je zelf overtuigd bent van het nut van het RM proces. Het zal een tussen weg moeten zijn tussen het huidige schema en het HIGP model. Bij het omstellen van het model moet je je ook afvragen of het concernbreed zou moeten, ook omdat iedere divisie met ander proces zit. Je kan daarbij wel leren van elkaars processen.

In het model noem je die zes fasen, waar zijn die op gebaseerd?
Dat zijn de zes fasen van het ontwikkelingstraject. Dit ondersteund de traceerbaarheid. Daarbij gaan de risico's van totale project omvang naar kleine detail risico's. En daarbij zie je ook dat er bepaalde aspecten dan niet meer veranderd kunnen worden. Daar moet je dus tijdig een beeld bij kunnen vormen.

Appendix C

Overview of all questionnaire used for collecting the expert estimations

Notification: The questionnaire was held in Dutch for reasons of simplicity and 'accessibility' for the respondents.

Enquête gevolgenomvang

Voor mijn afstudeeronderzoek ben ik een model aan het ontwikkelen voor het management van kansen en bedreigingen. In dit model ben ik op basis van een academische methode een module aan het opstellen die er voor dient om de onduidelijke, verbale omschrijvingen van gevolgen om te zetten naar numerieke waarden. Deze omzetting wordt vervolgens gebruikt om een concreter en accurater inzicht te krijgen in te verwachten opbrengsten van kansen en de kosten van bedreigingen. Door middel van deze enquête wil ik de ervaring van verschillende functies verzamelen, zodat ik deze in het model als richtlijn en input kan gebruiken. Bij voorbaat dank voor de medewerking.

Van verbaal naar numeriek, 'kwaliteit, omgeving en veiligheid'

Als een kans of een bedreiging zich voordoet, dan heeft dat een gevolg voor de 'kwaliteit, omgeving en veiligheid' van het project. De omvang van een dergelijk gevolg kan worden omschreven als 'zeer klein, klein, gemiddeld, groot' en 'zeer groot'. Om deze verbale omschrijving om te zetten naar een numerieke aanduidingen, moeten waarden worden toegekend aan deze omschrijvingen. Voor deze waarden wordt een bereik gekozen van 0 tot 1, waarin 0 staat voor 'geen gevolg' en 1 voor 'maximaal gevolg'. Belangrijk: het gaat dus niet om een kansverdeling, maar over de omvang van de gevolgen verdeeld binnen een schaal van 0 tot 1.

Wat vindt u in de schaal van 0 tot 1 de waarden voor de verschillende verbale termen voor kwaliteit? Omschrijf dit door voor iedere verbale term een bandbreedte te noteren in het onderstaande kader. *geef voor iedere verbale omschrijving de minimale waarde en de maximale waarde voor de omvang (e.g. zeer klein=0,0-0,11; klein=0,11-0,34 etc.) *belangrijk, de verdeling is niet per definitie evenredig

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Van verbaal naar numeriek, 'financieel'

Ook financieel kan het project gevolgen ondervinden van kansen en bedreigingen. Hiervoor zijn dezelfde verbale omschrijvingen toegepast; klein, klein, gemiddeld, groot en zeer groot. De kosten of opbrengsten zijn echter relatief aan de kostprijs van het project. Daarom is voor de numerieke aanduiding een bereik in percentages gekozen, waarbij 0% staat voor ‘geen gevolg’ en 100% voor ‘maximaal gevolg’. Door de percentages te nemen t.o.v. de kostprijs ontstaat er een relatieve schaal evenredig aan de project omvang.

Hoe zijn naar uw inzicht de verbale omschrijvingen voor de omvang van het financiële gevolg verdeeld over het percentueel aanduiding tussen 0% en 100%? Omschrijf dit in het onderstaande kader. *geef voor iedere verbale omschrijving de minimale waarde en de maximale waarde voor de omvang (e.g. zeer klein=0%-4%; klein=4%-15%) *belangrijk, de verdeling is niet per definitie evenredig, e.g. de waarde zeer groot zou ook van 30% tot 100% lopen

Verwachtingspatroon 'geld en tijd'

Zodra een kans of bedreiging zich manifesteert, kan het gevolg hebben voor meerdere factoren. Echter zijn alle gevolgen uiteindelijk terug te leiden naar ‘Geld’ en ‘Tijd’. Het bepalen van exacte waarden is daarbij een lastige taak. Om die taak te vereenvoudigen wordt daarom weer gebruik gemaakt van de verbale omschrijvingen voor ‘kwaliteit, omgeving en veiligheid’. Door voor iedere omschrijving een verwachte financieel en tijdtechnisch gevolg aan te geven, kan er een verwachtingspatroon worden opgesteld. Dit verwachtingspatroon zal geen exacte waarde geven, maar een indicatie van omvang van het gevolg vertaald in ´Geld´ en ´Tijd´. Voor geld wordt wederom gerekend in het percentage van de totale projectkosten. Ook voor tijd wordt er gerekend met een percentage. Dit percentage omschrijft de verwachte tijdswinst/vertraging t.o.v. de totale project duur, hierdoor ontstaat ook voor de tijd een relatieve schaal evenredig aan de project omvang. Ook kan het zo zijn dat het geen gevolg heeft voor geld, tijd of beide, dan volstaat de waarde ‘0’. Voorbeeld: ‘Als een bedreiging leidt tot een gevolg voor kwaliteit met de omvang ‘gemiddeld’, dan kan zorgt dat voor een financieel gevolg van 10% van de project kostprijs en een vertraging van 5% van de totale project duur.

Kwaliteit - geld

Als voor de kwaliteit de omvang het gevolg wordt beoordeeld met ‘zeer klein’, hoe groot is dan naar uw inzicht de omvang voor het financiële gevolg? Benoem deze waarde in procenten in het onderstaande kader. *geef één verwachte waarde voor het financiële gevolg in procenten, indien er geen financieel gevolg wordt verwacht dan volstaat de waarde "0"

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kwaliteit - tijd

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omgeving - tijd

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Als voor de veiligheid de omvang het gevolg wordt beoordeeld met ‘groot’, hoe omvangrijk is dan het gevolg voor de planning naar uw inzicht? Benoem deze waarde in procenten in het onderstaande kader. *geef één verwachte waarde voor het tijd technisch gevolg in procenten, indien er geen tijd technisch gevolg wordt verwacht dan volstaat de waarde "0"

Als voor de veiligheid de omvang het gevolg wordt beoordeeld met ‘zeer groot’, hoe omvangrijk is dan het gevolg voor de planning naar uw inzicht? Benoem deze waarde in procenten in het onderstaande kader. *geef één verwachte waarde voor het tijd technisch gevolg in procenten, indien er geen tijd technisch gevolg wordt verwacht dan volstaat de waarde "0"

Appendix D

TFN functions for the different input factors

Environment

	x_{min}	x_{mean}	x_{max}	Function TFN
limited	n/a	0,0	0,3	$y(x) = (-x/0{,}3) + 1 \mid x \in [0{,}0; 0{,}3)$
Small	0,025	0,275	0,525	$y(x) = 4x - 0{,}1 \mid x \in (0{,}025; 0{,}275]$ $y(x) = -4x + 2{,}1 \mid x \in (0{,}275; 0{,}525]$
Average	0,3	0,5	0,7	$y(x) = 5x - 1{,}5 \mid x \in (0{,}3; 0{,}5]$ $y(x) = -5x + 3{,}5 \mid x \in (0{,}5; 0{,}7]$
Large	0,475	0,725	0,975	$y(x) = 4x - 1{,}9 \mid x \in (0{,}475; 0{,}725]$ $y(x) = -4x + 3{,}9 \mid x \in (0{,}725; 0{,}975]$
Major	0,85	1,0	n/a	$y(x) = \frac{x}{0{,}3} - \frac{0{,}7}{0{,}5} \mid x \in (0{,}7; 1{,}0]$

Safety

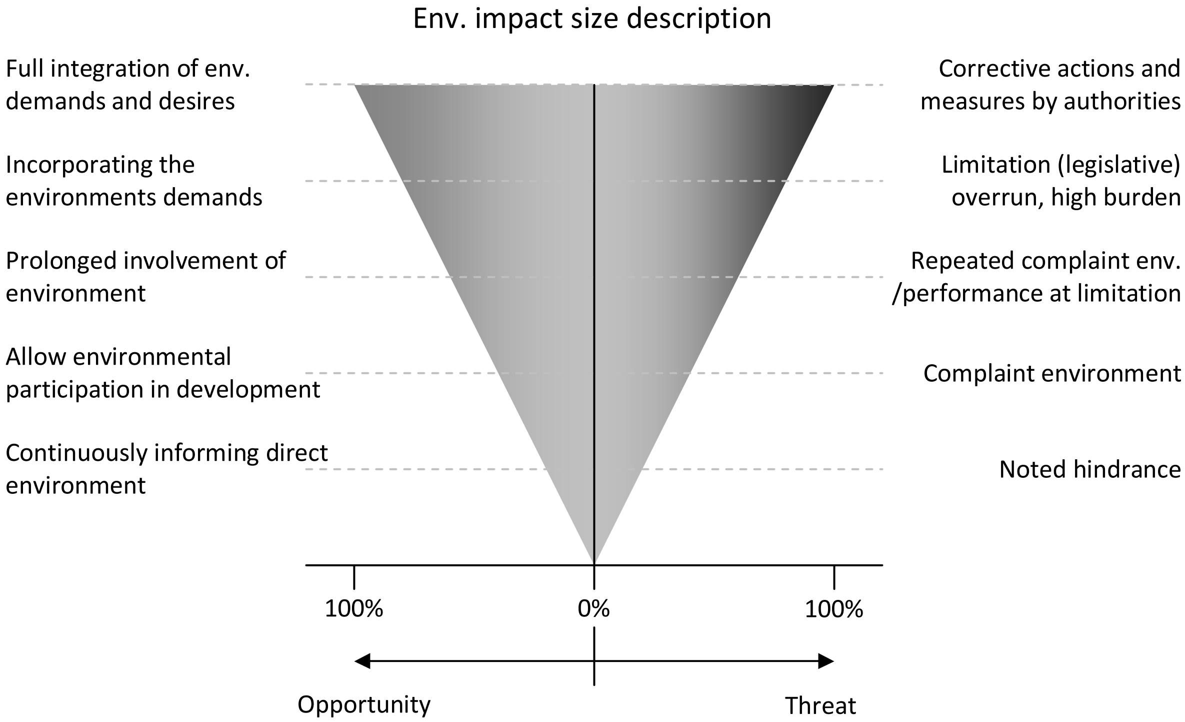
	x_{min}	x_{mean}	x_{max}	Function TFN
limited	n/a	0,0	0,4	$y(x) = (-x/0{,}4) + 1 \mid x \in [0{,}0; 0{,}4)$
Small	0,075	0,325	0,575	$y(x) = 4x - 0{,}3 \mid x \in (0{,}075; 0{,}325]$ $y(x) = -4x + 2{,}3 \mid x \in (0{,}325; 0{,}575]$
Average	0,35	0,55	0,75	$y(x) = 5x - 1{,}75 \mid x \in (0{,}35; 0{,}55]$ $y(x) = -5x + 3{,}75 \mid x \in (0{,}55; 0{,}75]$
Large	0,55	0,75	0,95	$y(x) = 5x - 2{,}75 \mid x \in (0{,}55; 0{,}75]$ $y(x) = -5x + 4{,}75 \mid x \in (0{,}75; 0{,}95]$
Major	0,7	1,0	n/a	$y(x) = \frac{x}{0{,}3} - \frac{0{,}7}{0{,}5} \mid x \in (0{,}7; 1{,}0]$

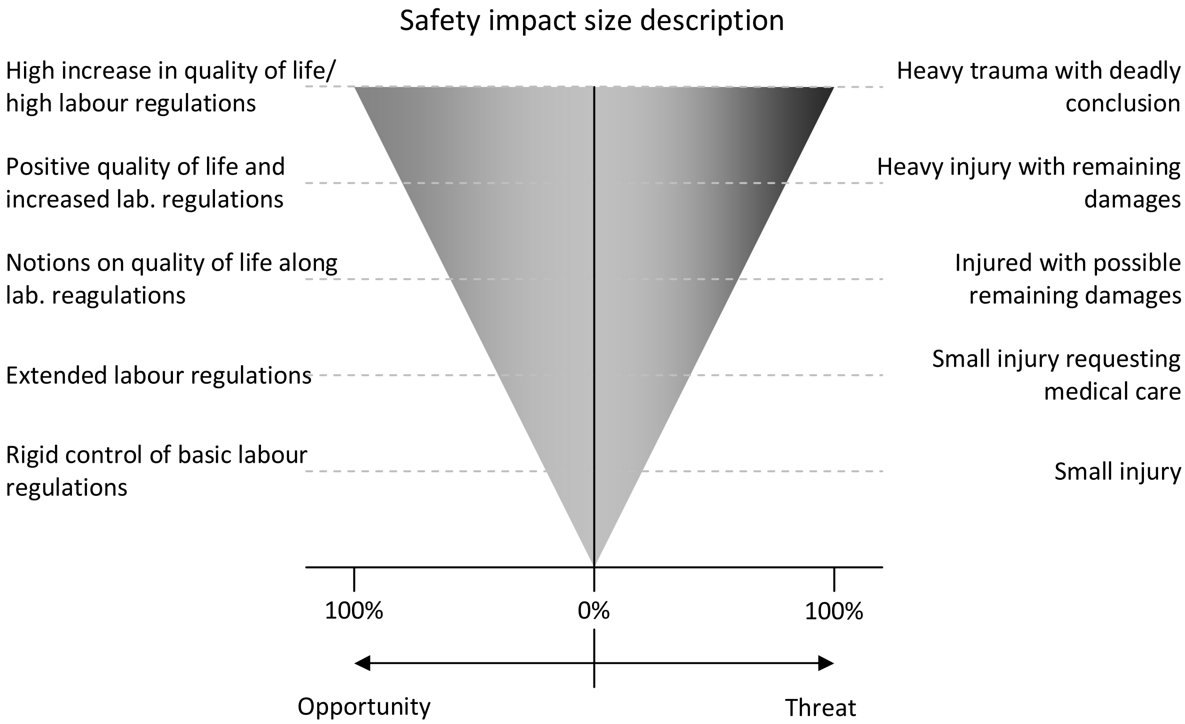
Money-Time

	x_{min}	x_{mean}	x_{max}	Function TFN
limited	n/a	0,0	2,0	$y(x) = (-x/2) + 1 \mid x \in [0{,}0; 2{,}0)$
Small	0,5	1,5	2,5	$y(x) = x - 0{,}5 \mid x \in (0{,}5; 1{,}5]$ $y(x) = -x + 2{,}5 \mid x \in (1{,}5; 2{,}5]$
Average	0,75	3,25	5,75	$y(x) = (x/2{,}5) - 0{,}3 \mid x \in (0{,}75; 3{,}25]$ $y(x) = (-x/2{,}5) + 2{,}3 \mid x \in (3{,}25; 5{,}75]$
Large	3,5	5,5	7,5	$y(x) = (x/2) - 1{,}75 \mid x \in (3{,}5; 5{,}5]$ $y(x) = (-x/2) + 3{,}75 \mid x \in (5{,}5; 7{,}5]$
Major	0,85	1,0	n/a	$y(x) = (x/2) - 2{,}25 \mid x \in (5{,}5; 7{,}5]$ $y(x) = 1{,}0 \mid x \in (7{,}5; 10{,}0]$

Appendix E

Risk impact size descriptions for the input factors





Appendix F

Screenshot from the different sheets in the developed tool. The input is taken from the filled out verification case based on energy management. Each sheet is indicated by their designated number or letter.

If requested, the documented tool can be provided in dialogue with the author.

Appendix F. Project Summary

Project Summary

Project	Test
Version	Verification
Date	5-3-2013 15:42

Direct construction cost (€)	€ 1.000.000,00
Total project duration (days)	50

Checked by:

Name

Signature

heijmans

Risk definitions

"*Risk* is the likelihood of occurrence of either an opportunity or a threat leading to loss or gain, together with the consequences of that occurrence at a certain moment in time."

"*Opportunity* is an event resulting in a positive influence (gain) on the project's objective functions in case of occurrence; if assigned a likelihood, the occurrence becomes a risk;

"*Threat* is an event resulting in a negative influence (loss) on the project's objective functions in case of occurrence; if assigned a likelihood, the occurrence becomes a risk."

"*Project risk management* is the systematic design, implementation and monitoring of activities in a cyclical structure providing a continuous, iterative process to identify, prioritize and analyze project risks and to devise, select and implement responses to optimize these risks."

Appendix F.1.a

1. Risk Identification

No.	Tag	Editor	Description
1	Ventilation capacity	Ruud van Beek	Standard calculation schemes create buffers, ventilation capacity far exceeds the requried volume, Initial investment for the installation is far to large because a smaller one would have been
2	Warranties suppliers	Ruud van Beek	DBFMO contract thus including maintenance thus warranties needed for the long term applied elements, warranties not covering for the entire M & O term of 20 years, additional maintenance and
3	Energy monitoring system	Ruud van Beek	Design has no usage of energy monitoring systems as of yet, place the monitoring system to gain insight in the usage, reduced energy usage followed by lower operating cost
4	Curved iso. glazing	Ruud van Beek	Curved isolating glazing unproven in usage, possible defects requiring repairs or replacement, additional expenses at maximum of original
5	Isolation existing structure	Ruud van Beek	Existing wall poorly isolated, EPC performance compromised, additional isolation is required
6	Quality wooden cladding	Ruud van Beek	Low qualtiy timber cladding, higher quality will require less maintainance and possible replacement, longterm less expensive in LCC
7	Heat exchanger	Ruud van Beek	No heat exchanger present in the ventilation system, placement leads to reduced loss of heat thus decreased heating, lower operating cost
8	BREEAM loan extension	Ruud van Beek	Additional bank loans achievable, loans provided when the design complies to the maximum BREEAM score, additional financial benifits for
9			
10			
11			
12			
13			
14			
15			
16			
17			
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23			
24			
25			

Appendix F.1.b

Nature	Catergory	Status
Optimization	Mechanical installation	Applied
Threat	Contractual	Ongoing
Opportunity	Electrical installation	Ongoing
Threat	Construction	Ongoing
Threat	Construction	Ongoing
Optimization	Construction	Applied
Opportunity	Mechanical installation	Ongoing
Opportunity	Financial	Ongoing

Appendix F.2.a

2. Risk Assessment

No.	Tag	Nature	Category
1	Ventilation capacity	Optimization	Mechanical installation
2	Warranties suppliers	Threat	Contractual
3	Energy monitoring system	Opportunity	Electrical installation
4	Curved iso. glazing	Threat	Construction
5	Isolation existing structure	Threat	Construction
6	Quality wooden cladding	Optimization	Construction
7	Heat exchanger	Opportunity	Mechanical installation
8	BREEAM loan extension	Opportunity	Financial
9	0	0	0
10	0	0	0
11	0	0	0

Appendix F.2.b

Certainty check	Money (€)	Planning (days)	Quality (%)	Environment (hinderance) (%)	Safety (%)
Certain	€ 25.000,00	5			
Uncertain			50%	0%	20%
Certain	€ 35.000,00	0			
Certain	€ 120.000,00	3			
Certain	€ 50.000,00	5			
Uncertain			60%	20%	20%
Certain	€ 48.000,00	0			
Certain	€ 200.000,00	0			

Appendix F.3.a

3. Control measures

No.	Tag	Nature	Catergory
1	Ventilation capacity	Optimization	Mechanical installation
2	Warranties suppliers	Threat	Contractual
3	Energy monitoring system	Opportunity	Electrical installation
4	Curved iso. glazing	Threat	Construction
5	Isolation existing structure	Threat	Construction
6	Quality wooden cladding	Optimization	Construction
7	Heat exchanger	Opportunity	Mechanical installation
8	BREEAM loan extension	Opportunity	Financial
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0

Appendix F.3.b

Control measure succes likelihood	Risk budgeting (€)	Planning impact (days)
Likely	€ 25.000,00	5
Doubtful	€ 22.320,31	2
Likely	-€ 35.000,00	0
Unlikely	€ 120.000,00	3
Unlikely	€ 50.000,00	5
Likely	€ 30.030,39	2
Likely	-€ 48.000,00	0
Doubtful	-€ 200.000,00	0
0	€ 0,00	0
0	€ 0,00	0
0	€ 0,00	0

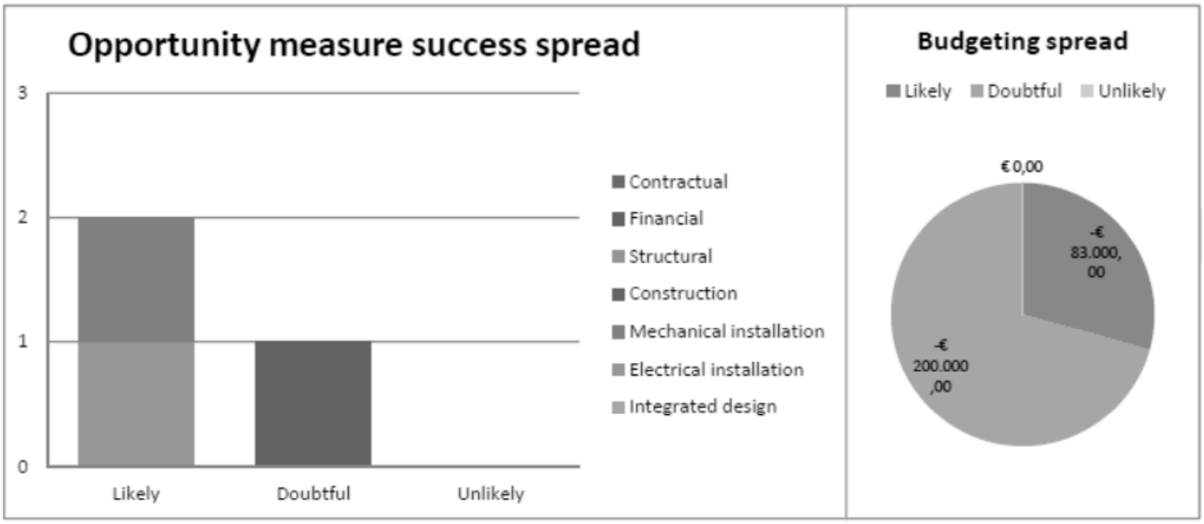
Appendix F.3.c

Response (reactive) measure	Target department	Response owner
If cracking occurs, contact supplier to obtain renewed infomration regarding proper treatments	Services	X

Appendix F.A.a

A. RMS - Statistics, Opportunities

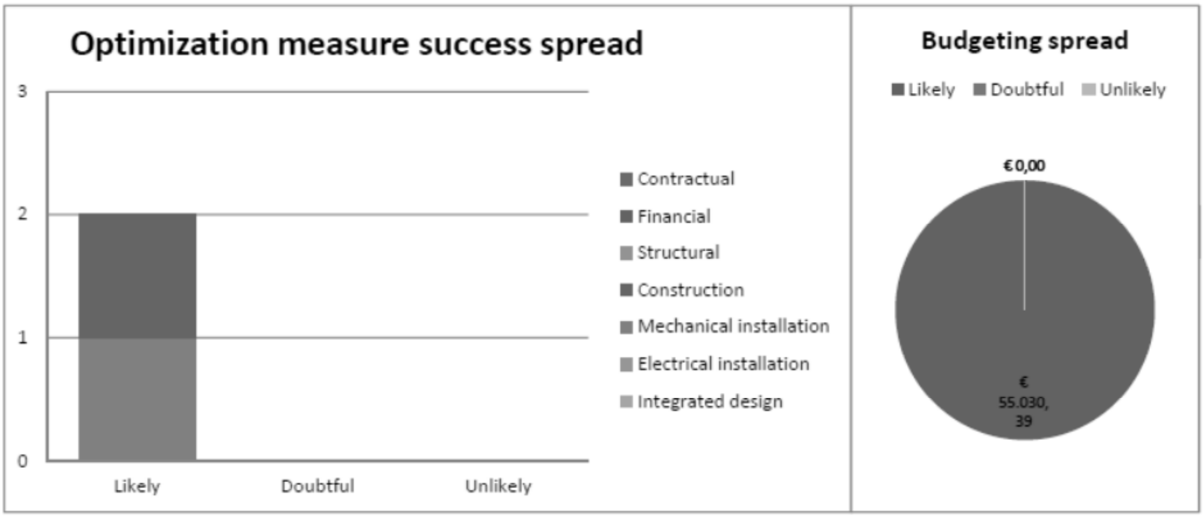
	Contractual	Financial	Structural	Construction	Mechanical installation	Electrical installation	Integrated design	Opportunity budgeting
Likely	0	0	0	0	1	1	0	-€ 83.000,00
Doubtful	0	1	0	0	0	0	0	-€ 200.000,00
Unlikely	0	0	0	0	0	0	0	€ 0,00
Total	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**-€ 283.000,00**



Appendix F.1.Ab

A. RMS - Statistics, Optimizations

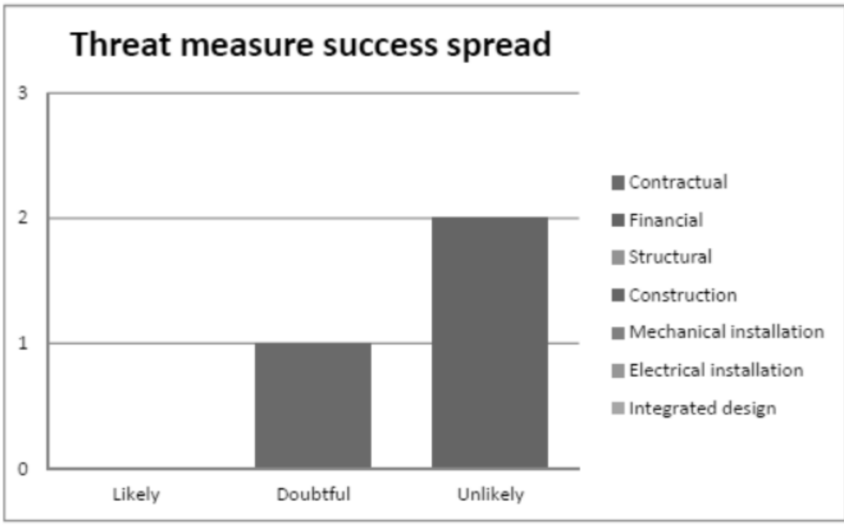
	Contractual	Financial	Structural	Construction	Mechanical installation	Electrical installation	Integrated design	Oppotimization budgeting
Likely	0	0	0	1	1	0	0	€ 55.030,39
Doubtful	0	0	0	0	0	0	0	€ 0,00
Unlikely	0	0	0	0	0	0	0	€ 0,00
Total	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**€ 55.030,39**

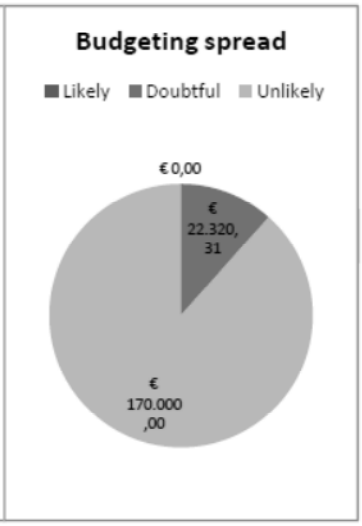


Appendix F.A.c

A. RMS - Statistics, Threats

	Contractual	Financial	Structural	Construction	Mechanical installation	Electrical installation	Integrated design	Threat budgeting
Likely	0	0	0	0	0	0	0	€ 0,00
Doubtful	1	0	0	0	0	0	0	€ 22.320,31
Unlikely	0	0	0	2	0	0	0	€ 170.000,00
Total	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**€ 192.320,31**





Appendix F.B

B. RMS - Budgeting

Project: Test | 5-3-2013 | sign.

Risk determination	
Likelihood category	Probability (%)
Likely	90
Doubtful	60
Unlikely	5

Project parameters	
Direct construction cost (€)	€ 1.000.000,00
Total project duration (days)	50

Risk budgeting scenarios

Best-Best	Best	Average	Worst	Worst-worst
-€ 283.000,00	-€ 283.000,00	-€ 16.361,27	€ 225.030,39	€ 247.350,71

Planning impact scenarios

Best-Best	Best	Average	Worst	Worst-worst
0,0	0,0	9,0	16,6	16,6

Project risk acceptance

Monetary risk acceptance (%)	10
Maximum risk budget	-€ 11.503,72
Minimum risk budget	-€ 21.218,83

Planning risk acceptance (%)	5
Maximum planning impact	9,14
Minimum planning impact	8,76

Total cost preventive measures and planning impact

Total cost minimum planning impact	€ 13.145,52
Total cost expected planning impact	€ 13.425,88
Total cost maximum planning impact	€ 13.706,24

Bonus €/d	€ 500,00
Fine €/d	€ 1.500,00

Total project risk budget

Min. accepted total risk & time budgeting	Av. Accepeted total risk & time budgeting	Max. accepted total risk & time budgeting
-€ 8.073,31	-€ 2.935,39	€ 2.202,53

Investment proactive control measures

Total cost proactive control measures	€ 43.200,00

Project Statistic summary

Risk type	Opportunities	Optimizations	Threats	Total
Initial no.	3	2	3	8
No. Cat. Likely	2	2	0	4
No. Cat. Doubtful	1	0	1	2
No. Cat. Unlikely	0	0	2	2

Appendix G

Screenshot from the different sheets in the developed tool. The input is taken from the filled out validation case. As case, a real life running or tendering case has been selected. Not all filled out entries from the documentation are shown for reasons of simplicity. Each sheet is indicated by their designated number or letter.

If requested, the documented tool can be provided in dialogue with the author.

Appendix G. validation Project Summary

Project Summary

Project	Project
Version	Validation
Date	5-3-2013 16:54

Direct construction cost (€)	€ 40.000.000,00
Total project duration (days)	300

Checked by:

Name

Signature

heijmans

Risk definitions

"Risk is the likelihood of occurrence of either an opportunity or a threat leading to loss or gain, together with the consequences of that occurrence at a certain moment in time."

"Opportunity is an event resulting in a positive influence (gain) on the project's objective functions in case of occurrence; if assigned a likelihood, the occurrence becomes a risk;

"Threat is an event resulting in a negative influence (loss) on the project's objective functions in case of occurrence; if assigned a likelihood, the occurrence becomes a risk."

"Project risk management is the systematic design, implementation and monitoring of activities in a cyclical structure providing a continuous, iterative process to identify, prioritize and analyze project risks and to devise, select and implement responses to optimize these risks."

Appendix G. validation 1.a

1. Risk Identification

No.	Tag	Editor	Description
1	Aquisition		Since O2 and DSM didn't pass, this project is suitable for installations in which the responsibilities regarding the installations are
2	EMVI points		For the construction parcel the price appears to be to high for the EMVI criteria, no points granted if that is the case, resulting in a bad competitive
3	Construction fraude		Past involvement has lead to a negative experience, client still takes this highly, bad
4	Tender		Even though integration is ongoing, the customer experience too much segregation between parcel, no commision for either/both parcels
5	Transfering contracts		Parcel 1 serves the contract in parcel 2 and the lab provider needs to be transferred as if it were an internal subcontractor, provider only bound rights and duty not by obligations, no control for parcel 1 on the contractual conditions of parcel 2 -
6	Liability		Signed for responsibility under errors between disciplines, limited liability rejected, design liabilities for contractor no longer limited to 1
7	Creditable		Client is creditable but the agreement has to be signed by proper legal entity, if signed by wrong entity, loss of credibility leading to high financial
8	BREEAM		Original Be Spoke process performed without Heijmans, demands were increased from 58% to 66% demanding additional demands, some of these demands can be achieved with limited resources, other have been accounted for (68K) in the budgeting, although extra time needed, if prove is delivered by experts then the price can
9	BREEAM		Due to cost issues exemplary perfomance demands are omitted by contractor, client obligates contractor to perform according to desired 66% BREEAM score, ommited criteria need to be designed leading to cost increases
10	Bank warant		The current warrant in place, client might claim this warrant without communications with the contractor about possible solutions, 5% financial damages during realisation and 2,5% after
11	Coordination obligation		Client omitted UAV 6.27 for contractor parcel 1, subcrontractor fails to make the planning or budget, a fine is pushed when delayed whilst the contractor of parcel 1 has no ability to place the
12	Omissions in fase B		Due to a singed buildingteam contract, the contractor has no right to claim additional works during realisation if not noted during the design and prepartion phase, surplus cost made for
13	Delays contractor		If the contractor requires an extension of the completion date all additional cost are his to bear, increased liability when the planning is not met,

Appendix G. validation 1.b

Nature	Catergory	Status
Opportunity	Contractual	Ongoing
Threat	Construction	Ongoing
Threat	Contractual	Ongoing
Threat	Integrated design	Ongoing
Threat	Contractual	Ongoing
Threat	Contractual	Ongoing
Threat	Contractual	Ongoing
Opportunity	Contractual	Ongoing
Threat	Contractual	Ongoing
Threat	Contractual	Ongoing
Threat	Contractual	Ongoing
Threat	Contractual	Ongoing
Threat	Contractual	Ongoing

Appendix G. validation 2.a

2. Risk Assessment

No.	Tag	Nature	Category	Certainty check
1	Aquisition	Opportunity	Contractual	Uncertain
2	EMVI points	Threat	Construction	Certain
3	Construction fraude	Threat	Contractual	Certain
4	Tender	Threat	Integrated design	Uncertain
5	Transfering contracts	Threat	Contractual	Uncertain
6	Liability	Threat	Contractual	Uncertain
7	Creditable	Threat	Contractual	Uncertain
8	BREEAM	Opportunity	Contractual	Certain
9	BREEAM	Threat	Contractual	Certain
10	Bank warant	Threat	Contractual	Certain
11	Coordination obligation	Threat	Contractual	Uncertain
12	Omissions in fase B	Threat	Contractual	Certain
13	Delays contractor	Threat	Contractual	Certain
14	Realisation milestone	Threat	Contractual	Certain
15	client discounts	Threat	Contractual	Certain
16	Building permit	Threat	Contractual	Certain
17	Building permit	Threat	Contractual	Certain
18	Specs 9600MI6/B6	Threat	Integrated design	Certain
19	Prep. mp parcel 1&2	Threat	Contractual	Certain
20	Specs B 01,02,02/90	Threat	Integrated design	Uncertain
21	Payment terms & cond.	Threat	Financial	Uncertain
22	Prep. mp parcel 1&2	Threat	Contractual	Certain
23	Cost BIM	Threat	Financial	Certain
24	Drainage	Threat	Structural	Certain
25	Drainage	Threat	Structural	Certain
26	Drainage	Threat	Structural	Certain
27	Noise limits con. pit	Threat	Structural	Uncertain
28	Noise measurements	Threat	Integrated design	Certain
29	Noise limits other	Threat	Construction	Uncertain
30	Vibration limits con. pit	Threat	Structural	Certain
31	Vibration limits other	Threat	Structural	Certain
32	Location	Threat	Structural	Certain
33	Location	Threat	Structural	Certain
34	Existing buildings	Threat	Structural	Uncertain
35	Construction pit	Threat	Structural	Certain
36	Construction pit	Threat	Structural	Uncertain

Appendix G. validation 2.b

Money (€)	Planning (days)	Quality (%)	Environment (hinderance) (%)	Safety (%)
€ 30.000,00				
€ 120.000,00	5			
€ 2.000.000,00				
		20%	0%	0%
€ 200.000,00	10			
€ 0,00	0			
€ 0,00	0			
€ 0,00	0			
€ 0,00	15			
€ 100.000,00	60			
€ 0,00	5			
€ 120.000,00				
		20%	0%	5%
		0%	0%	0%
€ 270.000,00	0			
€ 146.500,00	0			
€ 10.000,00	0			
€ 10.000,00	0			
€ 5.000,00	6			
		0%	70%	0%
€ 5.000,00	5			
		0%	70%	0%
€ 36.600,00				
€ 50.000,00				
€ 10.000,00	5			
€ 2.000,00	2			
		10%	5%	0%
€ 150.000,00	7			
		5%	5%	0%

Appendix G. validation 3.a

3. Control measures

No.	Tag	Nature	Category
1	Aquisition	Opportunity	Contractual
2	EMVI points	Threat	Construction
3	Construction fraude	Threat	Contractual
4	Tender	Threat	Integrated design
5	Transfering contracts	Threat	Contractual
6	Liability	Threat	Contractual
7	Creditable	Threat	Contractual
8	BREEAM	Opportunity	Contractual
9	BREEAM	Threat	Contractual
10	Bank warant	Threat	Contractual
11	Coordination obligation	Threat	Contractual
12	Omissions in fase B	Threat	Contractual
13	Delays contractor	Threat	Contractual
14	Realisation milestone	Threat	Contractual
15	client discounts	Threat	Contractual
16	Building permit	Threat	Contractual
17	Building permit	Threat	Contractual
18	Specs 9600MI6/B6	Threat	Integrated design
19	Prep. mp parcel 1&2	Threat	Contractual
20	Specs B 01,02,02/90	Threat	Integrated design
21	Payment terms & cond.	Threat	Financial
22	Prep. mp parcel 1&2	Threat	Contractual
23	Cost BIM	Threat	Financial

Appendix G. validation 3.b

Control (proactive) measure	Target department
Reduce margins through dialogue with client	AA
Aim at optimisations to reduce price and obtain the points, installations are within the stated scope	AA
N/A	BoD
Comission independent checks to judge the degree of integration and to what extend the offers are still separately judgeable	AA
Make terms and Conditions equal for all parties, the assignment is judged by the main contractor	AA
Guideline states that the design liabilities remain with the one responsible for the design, clearly stated in the agreements during phase A	AA
Research and check legal entity whilst signing	AA
Performe full BREEAM check, acoustics walls omitted, but full calculation of the acoustics performed with additional cost	Eng
None	Eng
No changes to the warrant, take into account and agree upon mandatory reporting with the bank in case of a claim	AA
Equal contract terms for subcontracts of both parcels, simplifies transitions, extend with clear planning, monitoring and agreements	AA
Thorough check of the design using BIM during the tender and preperation phase, 6,5 months to do the chack and gather a +/- list for optimisations	Eng
adjusted the construction planning to the stated completion date	Calc
Assess planning with experts and sub contractors, create buffer of about 3 months including 6 weeks for preparation delays	Calc
Since the risk is limitless, a clear monitioring of the planning is required; assess the proposed plan and planning with all stakeholders	AA
Reminding the client by indicating all required permits and requesting a copy of the request, permit and transcript	AA
Request a listing of the land use plan for a check with the proposed optimizations alongside the legislation	AA
Request client to change the terms	AA
Frequent evaluation regarding collaboration and additional process (team) management if required; mentioned in plan	AA
Engage an expierenced design coordinator and plan sufficient time to perform the adivisory role	Eng
Often seen term according to purchasing, offer the optimised agreement on terms of payment	Calc
Plan fase B with engineering and planning in mind, total cost if necessary are 270k (<1%) and bound in the common construction costs	Eng
State clearly in the plan, as transparent as possible, take cost from the original budgeting	Eng

Appendix G. validation 3.c

Control owner	Control cost	Control measure succes likelihood
		Likely
		Doubtful
		Unlikely
		Doubtful
		Likely
		Doubtful
		Likely
	€ 28.000,00	Likely
		Unlikely
		Doubtful
		Likely
		Likely
		Likely
		Likely
		Doubtful
		Likely
		Doubtful
		Unlikely
		Doubtful
		Likely
		Likely
		Doubtful
		Doubtful

Appendix G. validation 4.a

4. Response measures

No.	Tag	Nature	Catergory
1	Aquisition	Opportunity	Contractual
2	EMVI points	Threat	Construction
3	Construction fraude	Threat	Contractual
4	Tender	Threat	Integrated design
5	Transfering contracts	Threat	Contractual
6	Liability	Threat	Contractual
7	Creditable	Threat	Contractual
8	BREEAM	Opportunity	Contractual
9	BREEAM	Threat	Contractual
10	Bank warant	Threat	Contractual
11	Coordination obligation	Threat	Contractual
12	Omissions in fase B	Threat	Contractual
13	Delays contractor	Threat	Contractual
14	Realisation milestone	Threat	Contractual
15	client discounts	Threat	Contractual
16	Building permit	Threat	Contractual
17	Building permit	Threat	Contractual
18	Specs 9600MI6/B6	Threat	Integrated design
19	Prep. mp parcel 1&2	Threat	Contractual
20	Specs B 01,02,02/90	Threat	Integrated design
21	Payment terms & cond.	Threat	Financial
22	Prep. mp parcel 1&2	Threat	Contractual
23	Cost BIM	Threat	Financial
24	Drainage	Threat	Structural
25	Drainage	Threat	Structural
26	Drainage	Threat	Structural
27	Noise limits con. pit	Threat	Structural
28	Noise measurements	Threat	Integrated design
29	Noise limits other	Threat	Construction
30	Vibration limits con. pit	Threat	Structural
31	Vibration limits other	Threat	Structural
32	Location	Threat	Structural
33	Location	Threat	Structural
34	Existing buildings	Threat	Structural
35	Construction pit	Threat	Structural
36	Construction pit	Threat	Structural

Appendix G. validation 4.b

Control measure succes likelihood	Risk budgeting (€)	Planning impact (days)
Likely	€ 0,00	0
Doubtful	€ 0,00	0
Unlikely	€ 0,00	0
Doubtful	€ 0,00	0
Likely	€ 0,00	0
Doubtful	€ 0,00	0
Likely	€ 0,00	0
Likely	-€ 30.000,00	0
Unlikely	€ 120.000,00	5
Doubtful	€ 2.000.000,00	0
Likely	€ 269.090,91	3
Likely	€ 200.000,00	10
Likely	€ 0,00	0
Likely	€ 0,00	0
Doubtful	€ 0,00	0
Likely	€ 0,00	15
Doubtful	€ 100.000,00	60
Unlikely	€ 0,00	5
Doubtful	€ 120.000,00	0
Likely	€ 535.757,58	5
Likely	€ 0,00	0
Doubtful	€ 270.000,00	0
Doubtful	€ 146.500,00	0
Doubtful	€ 10.000,00	0
Likely	€ 10.000,00	0
Likely	€ 5.000,00	6
Likely	€ 0,00	0
Likely	€ 5.000,00	5
Likely	€ 0,00	0
Likely	€ 36.600,00	0
Doubtful	€ 50.000,00	0
Likely	€ 10.000,00	5
Likely	€ 2.000,00	2
Likely	€ 637.794,49	6
Doubtful	€ 150.000,00	7
Doubtful	€ 638.448,08	6

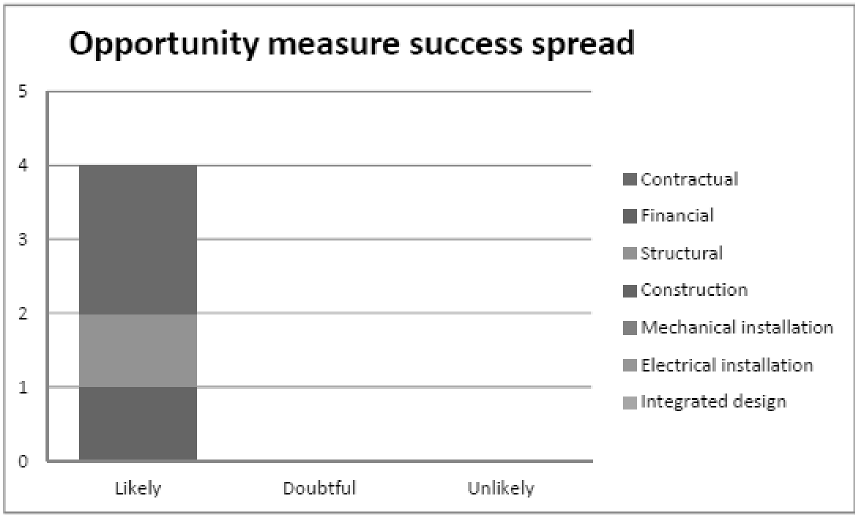
Appendix G. validation 4.c

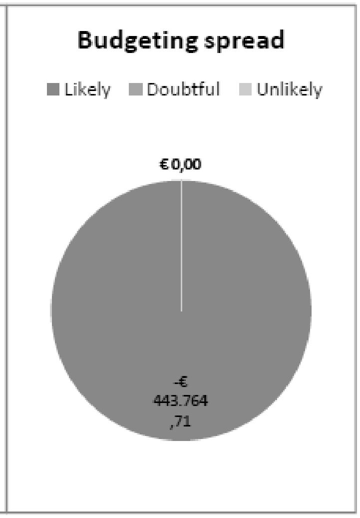
Response (reactive) measure	Target department	Response owner
Evaluate loss	AA	
Evaluate loss	AA	
Evaluate loss	AA	
Evaluate loss	AA	
Return on transferred information to judge its contents and discuss the proper course for both	AA	
Limit the deviations by increased monitoring and early reporting	AA	
Open discussion and try to nullify original	BoD	
Try to provide suitable, benificial alternatives	Eng	
N/A		
Engage in discussions to gain insight in reasoning and provide suitable optimization or solution with compremisses	AA	
Limit wrongdoings with additional monitoring	Eng	
N/A		
Limit with additional workers or predefined solutions for bottle neck elements	Eng	
Evaluate loss	AA	
Evaluate loss	AA	
N/A		
Start project of permit request as soon as possible, single out optimizations and their effects	Eng	
N/A		
N/A		
N/A		
Try to obtain resource asap, plan the actions of outstanding invoices	AA	
Evaluate loss	AA	
N/A		
N/A		
Add addtional costs to expenses and reduce	Calc	
N/A		
Pause all activities, identify source and consder optimizations, in dicsussion with client	Eng	
N/A		
Pause all activities, identify source and consder optimizations, in dicsussion with client	Eng	
Pause all activities, identify source and consder optimizations, in dicsussion with client	Eng	
Pause all activities, identify source and consder optimizations, in dicsussion with client	Eng	
Skip pile, proceed with next, meanwhile remoce part of all foundation before specific continuation	Eng	
N/A		
N/A		
Restore sheet piling with additional fortifications	Civ	
Assess damages and repair accordingly	Civ	

Appendix F. validation A.a

A. RMS - Statistics, Opportunities

	Contractual	Financial	Structural	Construction	Mechanical installation	Electrical installation	Integrated design	Opportunity budgeting
Likely	2	0	1	1	0	0	0	-€ 443.764,71
Doubtful	0	0	0	0	0	0	0	€ 0,00
Unlikely	0	0	0	0	0	0	0	€ 0,00
Total	2	0	1	1	0	0	0	-€ 443.764,71

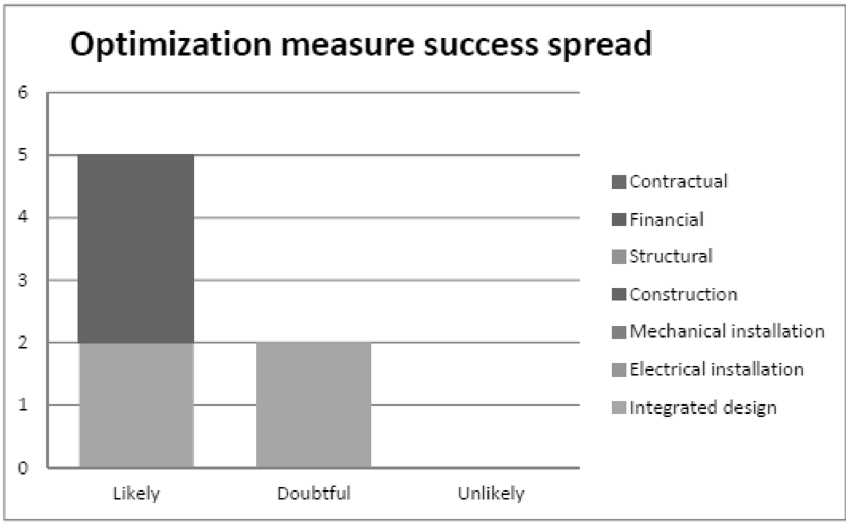


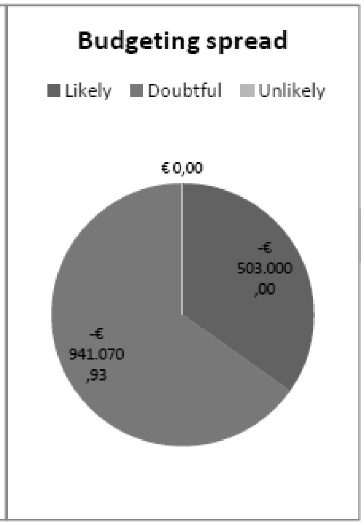


Appendix F. validation A.b

A. RMS - Statistics, Optimizations

	Contractual	Financial	Structural	Construction	Mechanical installation	Electrical installation	Integrated design	Oppotmization budgeting
Likely	0	0	0	3	0	0	2	-€ 503.000,00
Doubtful	0	0	0	0	0	0	2	-€ 941.070,93
Unlikely	0	0	0	0	0	0	0	€ 0,00
Total	0	0	0	3	0	0	4	-€ 1.444.070,93

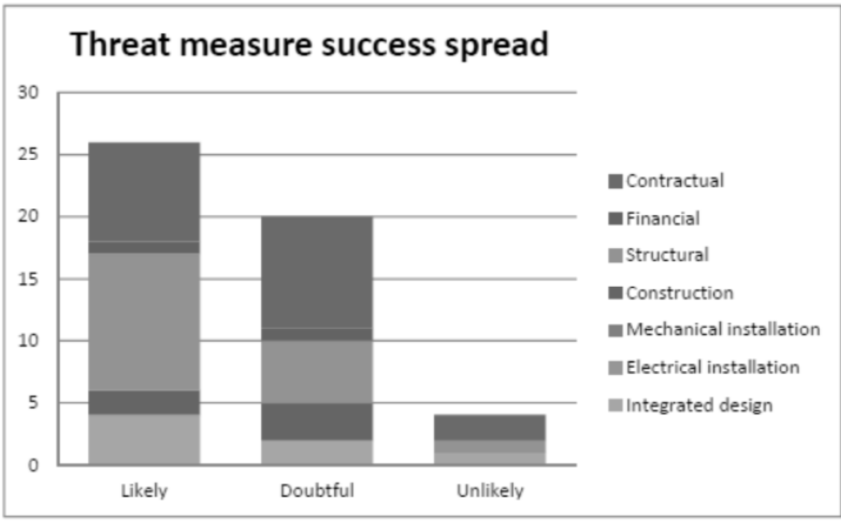


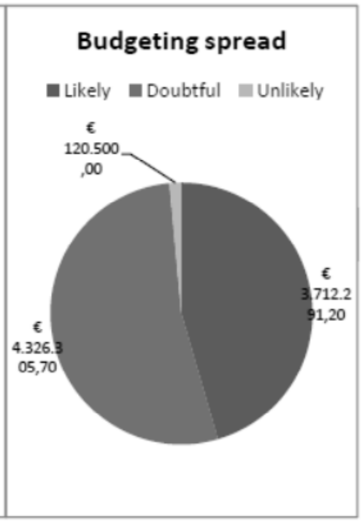


Appendix F. validation A.c

A. RMS - Statistics, Threats

	Contractual	Financial	Structural	Construction	Mechanical installation	Electrical installation	Integrated design	Threat budgeting
Likely	8	1	11	2	0	0	4	€ 3.712.291,20
Doubtful	9	1	5	3	0	0	2	€ 4.326.305,70
Unlikely	2	0	1	0	0	0	1	€ 120.500,00
Total	19	2	17	5	0	0	7	€ 8.159.096,90





Appendix G. validation B

B. RMS - Budgeting

Project:	5-3-2013	sign.

Risk determination	
Likelihood category	Probability (%)
Likely	90
Doubtful	50
Unlikely	10

Project parameters	
Direct construction cost (€)	€ 40.000.000,00
Total project duration (days)	300

Risk budgeting scenarios

Best-Best	Best	Average	Worst	Worst-worst
-€ 1.887.835,64	-€ 1.594.335,64	€ 1.347.487,12	€ 4.912.696,31	€ 8.159.096,90

Planning impact scenarios

Best-Best	Best	Average	Worst	Worst-worst
-18,6	-12,6	59,9	142,5	204,4

Project risk acceptance

Monetary risk acceptance (%)	10	Planning risk acceptance (%)	5
Maximum risk budget	€ 1.428.416,80	Maximum planning impact	62,10
Minimum risk budget	€ 1.266.557,44	Minimum planning impact	57,74

Total cost preventive measures and planning impact

Total cost minimum planning impact	€ 288.680,30
Total cost expected planning impact	€ 299.580,89
Total cost maximum planning impact	€ 310.481,48

Bonus €/d	€ 0,00
Fine €/d	€ 5.000,00

Total project risk budgeting (inc. Cost preventive measures)

Min. accepted total risk & time budgeting	Av. Accpeted total risk & time budgeting	Max. accepted total risk & time budgeting
€ 1.555.237,74	€ 1.647.068,01	€ 1.738.898,29

Investment proactive control measures

Total cost proactive control measures	€ 108.500,00

Project Statistic summary

Risk type	Opportunities	Optimizations	Threats	Total
Initial no.	4	7	50	61
No. Cat. Likely	4	5	26	35
No. Cat. Doubtful	0	2	20	22
No. Cat. Unlikely	0	0	4	4

Summary – English

Ten page summary of the report written in English.
Including personal resumé.

CORE BUSINESS: SEIZING OPPORTUNITIES IN RISK MANAGEMENT
A Generic Fuzzy Logic Prediction and Monte Carlo Simulation Method

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13-03-2013

ABSTRACT
Implementing innovations and extending the core business increases both project opportunities and threats. Securing profit margins requires construction companies to redevelop their risk management process to prevent threats and promote opportunities. This research provides a renewed risk management method based on theory and practice. The traditional definitions terms involved with risk management are redefined and a framework is proposed using the definitions as restraints. In turn the activities in the framework are used as outline to create a supportive tool composed of the risk analysis and risk management principles. The main activities encompass identification, assessment and development of control and response measures. The assessment is supported by a combined fuzzy logic prediction system and Monte Carlo simulation tool to provide each risk with impact characteristics in terms of money and time. The renewed method provides a verified and validated approach to increase internal implementation and external application of risk management.

Keywords: Risk analysis, Risk management, Fuzzy logic, Monte Carlo simulation

INTRODUCTION
Risk is commonly seen as threat, it equally provides plentiful opportunities to differentiate the organization relative to the competitors creating a competitive advantage. Obtaining that advantage relies on identification and management those risks. Such an advantage expresses itself in e.g. better cost control, solution driven design practices and the ability to implement innovations. Recently lots of attention has been developed towards innovative forms of collaboration. Integrated collaboration between different disciplines is deployed in an increasing manner by both clients and contractors. Most of the research regarding risk management is descriptive-driven, lacking the generation of pragmatic and prescriptive results (Staveren, 2009). Rather than developing a new methodology, this research aims to adopt the method as proposed by Alaneme and Igboanugo (2012) and Nasirzadeh et al. (2008) and altering it to fit the current developments in practice generates an academic approach with practical applicability. Simultaneously, the method will encourage and urge the market to adopt integrated contracts providing flexibility, sustainability and durability for current and future projects by seeking out opportunities and accepting risks responsibly.

CONTEXT

According to Zook and Allen (2001) is '*the foundation of sustained, profitable growth a clear definition of a company's core business*', a statement which is gaining foothold in the construction market. Clients are increasingly desiring a facility that will guaranty the ability to focus solely on their core business activities (Fleuren, 2012; Titulaer, 2012), resulting in a paradigm shift for construction projects. New ways are being sought to raise the level of environmental and economical performance whilst simultaneously raising the quality of the facility. Achieving these goals means extending the definition of the construction market to include conception, construction, operations, retrofitting and maintenance of the build environment (ECTP, 2005). Rather than reducing the activities, the construction market needs to extend its core business. Normally risks are regarded as an inherent aspect of the market, thinking in and seizing of opportunities is still perceived as a distinguishing feature (ING Economisch Bureau, 2012). Opportunities obtained by extending the core business, lead to new profit margins. These margins are small thus need securing via proper risk control measures. Developing and deploying these measures relies on proper risk management (RM). Though the responsibilities increase once extending the core business, it also enlarges the influence which can be expressed on the risks. With this influences comes the possibility to improve the business' RM.

Improving the RM requires a grasp on status quo, hence this research has been conducted at Heijmans Non-residential (Heijmans Utiliteit). Operational processes need improvement to maintain the momentum of the integral advancement. Such improvements include cost reduction, process improvement and selecting projects based on margin rather than volume. Due to this focus, Heijmans provides a suitable platform and subject to conduct research regarding RM. Based on the centre problem of this research how to secure profit margins bij managing (core business extension) risks, the following research question was devised: '*How should Heijmans either improve or redevelop their risk management (RM) method to achieve the desired increase in internal implementation and external, commercial application*?' This question indicates that the current method doesn't function as desired. Effectively foreseeing in the aim of either improving or redeveloping first requires the identification and analysis of the problems that led to this non- or dysfunctional state. Hence the current method's components were assessed through interviews with the users, workgroup discussions and a *within case study* of the functioning, stating the following causes:

- Risk over opportunity: Due to the traditional perception of risk as a negative element the overall RM process focuses on the risks rather than the opportunities, leading to an unequal focus-division between risks and opportunities;
- Limited iteration: RM involves feedback processes from the developed measures towards the original design and management of the activities, the iterative process that allows for such feedback is hardly present let alone applied;
- Reduced team effort: Although RM is supposedly a collective team effort, due to insufficient knowledge users are incapable of providing a uniform team effort indicating the need for a redevelopment or improvement of the supporting tool;
- Shortcoming strategy: Without an overarching strategy RM has no predefined purpose, through a strategy RM can be deployed to identify specific opportunities and risks adhering to the clients expectations, allowing for result validation.

RISK CONCEPTS AND DEFINITIONS

In the current RM the emphasis is placed on risks as a negative entity instead of a supposed equally divided perception between risks and opportunities. Redeveloping Heijmans' risk management requires an understanding of the basic concepts, negating the subjective perception with clear definitions. The concepts are assessed through literature study, gathering, analysing, comparing and selecting applicable knowledge. The target is to obtain applicable definitions of these concepts serving a basic understanding and stimulating a positive perception. Among the many studies regarding risk management, the most common definition of risk proposed by for instance Jaafari (2001), is the exposure to loss or gain. This exposure in turn is described as the probability of occurrence of loss or gain multiplied by the magnitude of its impact. Probability ranges from 'certain events' with an occurrence rate of 100%, to events with a non-occurrence rate of 0%. Uncertainty indicates the varying probability of occurrence of events in the range between these two extremes (Jaafari, 2001). The outcome of the assessment proved however that the traditional perception and explanation of the concept risk to be inapplicable. Combining the findings led to renewed definitions for the terms risk, threat and opportunity. Risk indicates the likelihood of an event occurring, regardless of the nature of this event. An event with a positive gain for the project's objective function is called an opportunity, negative gain indicates a threat. Combined, 'opportunity and threat' are interchangeable with the concept 'risk', henceforth the leading definition for 'risk' in this research. Risk analysis (RA) and RM are required processes to seize opportunities and mitigate threats. RA foresees in the process-based activities needed to obtain all information regarding the origin, influence and likelihood of project risks. Based on this information, suitable response measures are developed to promote opportunities and mitigate threats. RM is the systematic implementation of the response measures. Due to the dynamic nature of project risks, RM adheres to a cyclical structure to provide a continuous, iterative process.

RISK MANAGEMENT FRAMEWORK

In order of structuring the process of RM and the necessary activities, a framework is devised. Embedding the renewed RM concept definitions provides an outline and direction for these activities. The framework should also foresee in the ability to implement actions developed to either promote or prevent risks, requiring an iterative process for continues feedback. Through literature studies and cross-comparison, the market's current and prevalent methods were assessed to obtain applicable elements for the framework. With the outline in place, a structure can be devised. In turn, activities are identified and assessed from which suitable activities are selected and placed in the structure, resulting in the proposed RM framework as shown in Figure 1**Fout! Verwijzingsbron niet gevonden.**. The main thought is to create a process that provides information regarding the identified risks in an increasing manner. At the basis of the framework lie the RA and RM principles resulting from the RISMAN method; aside from its current implantation, this method also allows for complete and proven integration in the overall project process. The activities embedded in the framework, are selected to create an unambiguous process with a clear stepwise procedure negating perceptive subjectivity. The RA principle, the underlying activities and subsequent products create a linear process of risk identification, assessment and response development. During these activities the equally divided focus on opportunities and threats can be monitored. The RM principle activities provide continues updates for the PMP, ensuring the iterative process nature. The proposed framework structures all activities in an initially linear and continuous iterative process.

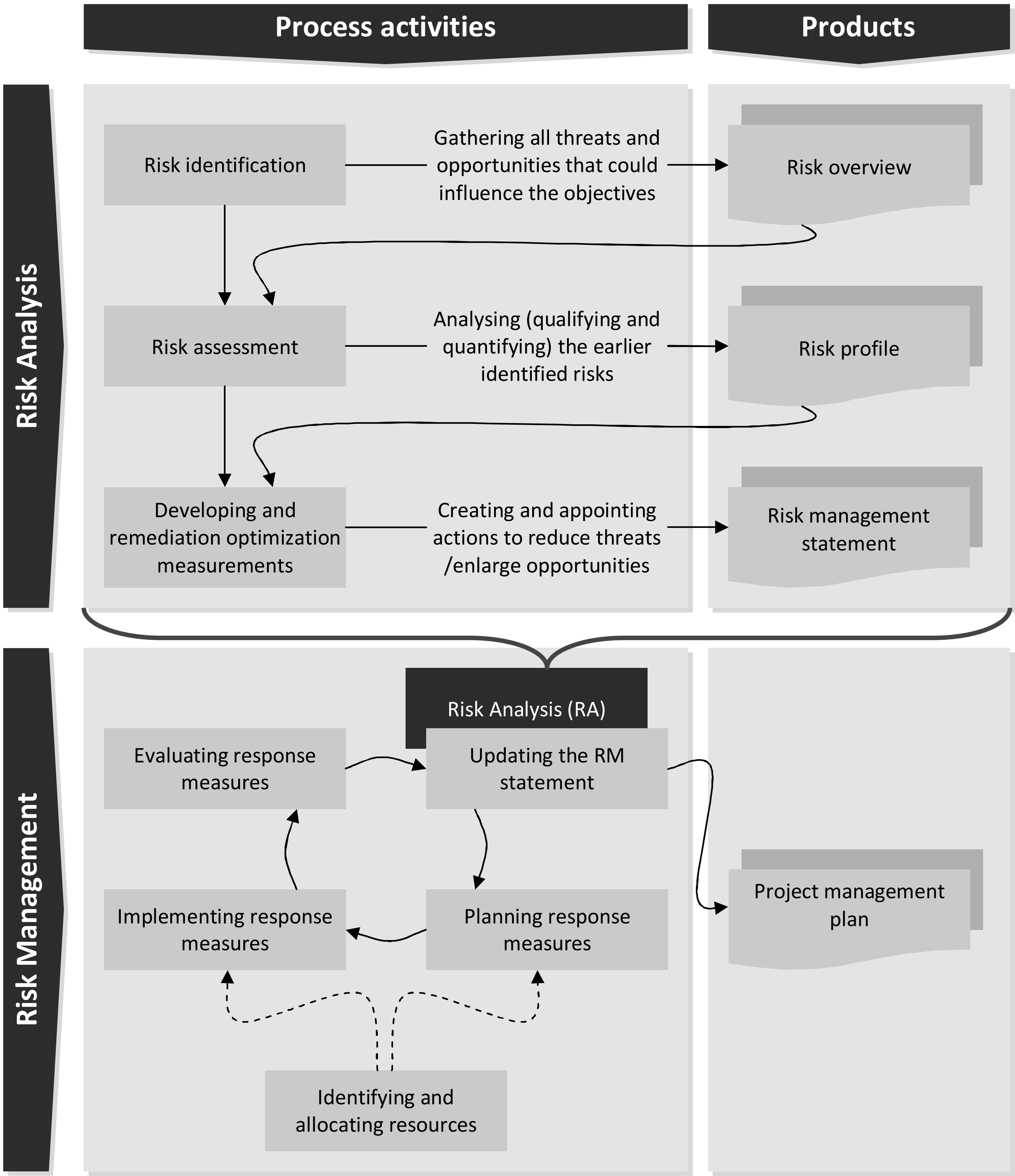

Figure 1: Proposed RM framework including the selected activities and products embedded in their respective RM principle; the framework focuses on the internal process, hence the overarching strategic step is, currently, omitted.

FRAMEWORK BASED TOOL

Working with the proposed framework foresees in an activity based stepwise process structure. Engaging in the process with the activities as a baseline provides an unambiguous approach, clearly stating the purpose and aim of every step. Following the purpose and aim, information is gathered during every step with an increasing amount of detail. This information needs to be stored in an equally structured manner to prevent loss of knowledge and to promote traceability. Such a manner is provided through a tool in which the information can be stored. Simultaneously, a tool will also support and secures the stepwise process structure by defining which information needs to be gathered to complete each step. With the framework as outline for the tool, the tool itself is created with suitable methods selected through literature studies with comparable subjects or applications. The main aim is to create a tool that provides the process with a simplistic structure, thus making the it understandable and applicable for every user. The outcome is an excel based tool in which each step represents the identified activities in the framework. Information gathered in the steps is stored in the documentation scheme of the tool. With every increase in information, the following product-type is produced. Leading are the activities from the RA process, with their aim and subsequent information defined as following:

Risk Identification

The first activity is documenting the basic identification consisting of the description, nature, category (discipline based) and status. For sakes of traceability, each risk also receives a number, tag and the editor of the risk is obliged to note his name.

Risk assessment

Following the risk information transferred from the identifcation, this activity aims at defining the risk characteristics in terms of the factors 'money' and 'time'. Whilst defining these characteristics, the editor has to indicate whether he or she is certain regarding the values of these characteristics. In case the editor is certain, the expected impact in terms of money (€) and planning (calendar days) can be documented. When however the editor is uncertain of these values or there is no knowledge present, the impact in terms of 'money' and 'time' can be estimated using Fuzzy Logic. The editor indicates his or her estimation regarding the impact of the risk on the input factors 'quality, environment and safety' in terms of percentages; 0% means no impact and 100% means maximum impact. These values are treated as input for the fuzzy risk magnitude prediction system based on a Mamdani fuzzy control system. The input passes through fuzzification, rule base-inference and defuzzification to obtain the output values (Nasirzadeh et al., 2008). First the input factors quality, environment and safety are qualified through linguistic descriptions. For this transformation the Likert 5-point attitudinal scale was applied, providing each factor with the scales 'limited, small, average, large and major' (Alaneme and Igboanugo, 2012). For each description, a triangular distribution is provided based on expert knowledge, resulting in a triangular fuzzy number (TFN). For this research 20 experts with different professions were approached within Heijmans to gain a broad insight. In total 8 experts responded to the questionnaire, providing the estimations for the TFN's. Though insufficient for proper calibration, the gathered figures where used as input for the following functions:

$$A_i = (x_{min}, x_{mean}, x_{max}) \ \textit{where} \ A\colon y(x) = (ax + b) + (cx + d) \mid x \in x_{min}, x_{max} \qquad (1)$$

Where A=TFN; i=ith TFN for each factor (i=1,2,3,4,5); x_{min}, x_{mean} and x_{max} are the minimum, mean and maximum values for the TFN; a and c describe the slope of both sides; c and d describe the point where the function cuts the y-axis for y(x)=0. Combining this TFN-function with the linguistic descriptions and the expert estimations results in membership functions for both the input and output factors. Figure 2 displays such a membership function for the

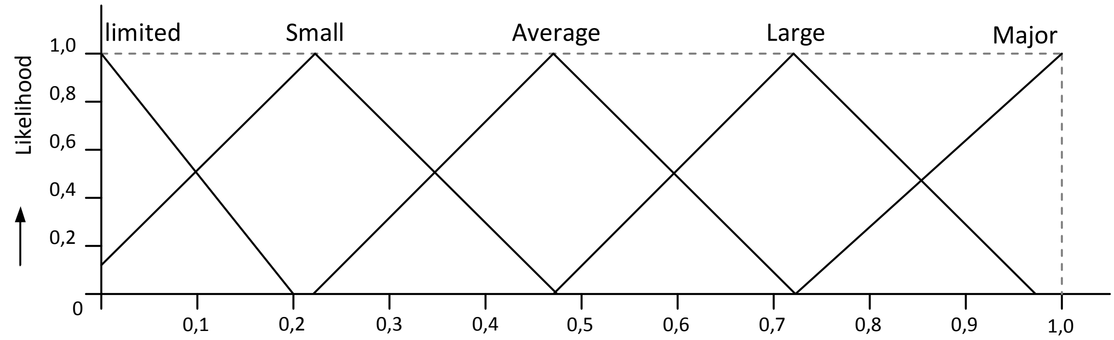

Figure 2: Visualization of the membership functions of the TFN's in the factor Quality

factor 'quality'. Nasirzadeh et al. (2008) state that '*the rules connect the input values with the output values and are based on the fuzzy state description that is obtained by the definition of the linguistic descriptions*'; e.g. if input TFN A:y for a given x, then the output TFN U is stated with y x ∈ (0,0;y(x_A)]. This approach in which the output TFN is limited with the input factor's degree of fulfilment (α) is called the minimum-method, also known as the MAX-MIN-inference (Schulte, 1994). This inference is operated through logical if-then functions. Experts were requested to estimate the impact in terms of money and time for every input factor's linguistic descriptions in percentages relative to the total construction cost and total project duration. After the inference, defuzzification is performed, altering these input factors into crisp value outputs for the factors 'money' and 'time'. Nasirzadeh et al. (2008) proposed the use of the 'centre of area (COA) method' for the defuzzification:

$$x^{COA} = \frac{\int_x x * y(x)dx}{\int y(x)dx} \quad (2)$$

Where x^{COA} = the x-value of the COA, thereby the crisp value risk characteristic of that output factor; and y(x) is the membership function of the TFN in subject. Performing this calculation, the degree of fulfilment of the input factor should be taken into account. Substituting function (2) in this function and taking into account cases where a single inference relates to multiple output factor TFN's for a single α, results in a single adjusted membership defuzzification integral:

$$x^{COA} = \frac{\int_x x * y_1(x)dx}{\int y_1(x)dx} + \cdots + \frac{\int_x x * y_n(x)dx}{\int y_n(x)dx} \mid n = 1,2,3,4,5 \quad (3)$$

$$\bar{x}^{COA} = \sum_{i=1}^{m} (x_i^{COA})/m \quad (4)$$

Where n = the total number of TFN's implied through inference. But not only the output factors can encompass multiple TFN's, the same goes for the input factor TFN's. If that case should arise, the crisp value for each separate input factor TFN can be calculate through inference and defuzzification, after which the crisp values are added and divided by the total number of values thereby providing the average. This is provide in function (4) where m = the total number of input factor TFN's defined by the input value. The extend of membership, y(x), determines the α for each input factor TFN; since the x^{COA} of every defuzzification is calculated using the different α's, a weight factor is included into the overall calculation. Through this intricate prediction system, uncertain risk characteristics can be estimated based on the size of their impact.

Control & response measures

With the characteristics known, suitable control proactive measures are developed to promote, increase or obtain opportunities and to prevent, mitigate or transfer threats. The editor needs to document the control measure description, target department, control owner, control cost and the control measure success likelihood category. The latter is a category-based aspect, defining how successful the developed measure will be when implemented. This success likelihood has been divided into the categories (SLC) 'Likely, Doubtful and Unlikely'. Actual values in percentages will substitute these linguistic descriptions later on, but defining these values is a task given to the decision making unit (DMU). In case a control measure has not been developed or is not successful, a response measure is required when a risk does manifest itself. The information documented for these reactive response measures is identical to that of the control measures, minus the control cost (these are incorporated in the expected risk budgeting and planning impact) and the SLC. Prioritization is provided by filtering the risks on the expected risk budgeting and planning impact. Risks with a high budgeting or impact might require more urgent attention, especially if the SLC is considered 'Unlikely'.

Risk management statement (RMS)

Once all risks are identified and assessed, they are statistically summarized. This summary displays the number of opportunities, optimizations or threats in each SLC, subdivided into the discipline categories. This provides an overview of the total number of entities for each specific risk nature and how likely these risk are managed during the RMP. Their individual characteristics are altered into a expected total impact spread for both 'money' and 'time'. For the latter the DMU first needs to identify the values for the SLC's, serving as input for the Monte Carlo simulation (MCS). This MCS provides the minimum, maximum and mean expected budgeting and planning impact for the entire project, documented as scenarios. Based on this expected spread the DMU can then determine the degree of risk acceptance, calculated through the confidence interval:

$$\bar{X}_{max} = \bar{X} \pm z\frac{\sigma}{\sqrt{n}} \quad (5)$$

Where $\overline{X}_{min}$, $\overline{X}_{max}$ are the minimum and maximum boundaries of the confidence interval respectively; $\overline{X}$ is the calculated mean from the MCS; z is the cumulative probability adhering to the confidence level $P=(100-P^{-1})$, derived from the statistic t-table (Nieuwenhuis, 2009); σ is the standard deviation MCS; and n is the number of simulations performed in the MCS. The planning impact is altered into values for the factor 'money' based on client discounts or contractor bonuses, finally prompting the risk-acceptance adjusted total project risk budgeting, explained as spread with a minimum, average (expected) and maximum value. This final value is compared to the project margins by the DMU to determine the net return on the project.

VERIFICATION AND VALIDATION

For the purpose of verifying and validating the developed tool two cases were assessed. For the verification several energy-management risks were conceived and implemented. The project which has been selected to serve as case for the validation (from this point onwards indicated as '*project*') is a combined tender for both the construction and installations. The project cost are in between €37.500.00,- and €42.500.000,-, with a size between 40.000 and 50.000 m^2 and the duration of realisation has been assumed at 300 working days. For the documentation a price of €40.000.000,- has been assumed. All risks identified using the former (currently applied) model are transferred to the RMS of the renewed tool.

From the RMS the basic statistics can obtained fairly easy. In the project 4 opportunities, 7 optimisations and 50 threats have been identified. All opportunities' SLC's have been assumed likely and are estimated at a total of -€443.765,-; for the optimizations the estimated outcome is -€1.444.071,- with the measures mostly assumed likely, and; the total unadjusted impact for the threats is €8.159.097,- with half of the measures perceived as likely and nearly the complete other half as doubtful. From these figures, as shown in Figure 3, it becomes clear that the emphasis should be placed on reducing and mitigating the project's threats.

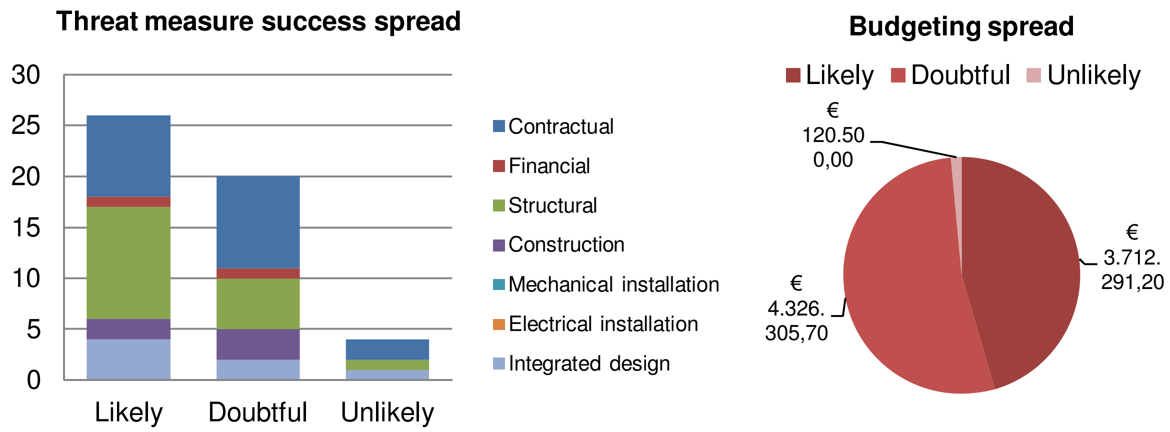

Figure 3: Outcome of the SLC's and budgeting for the threats in the validation case

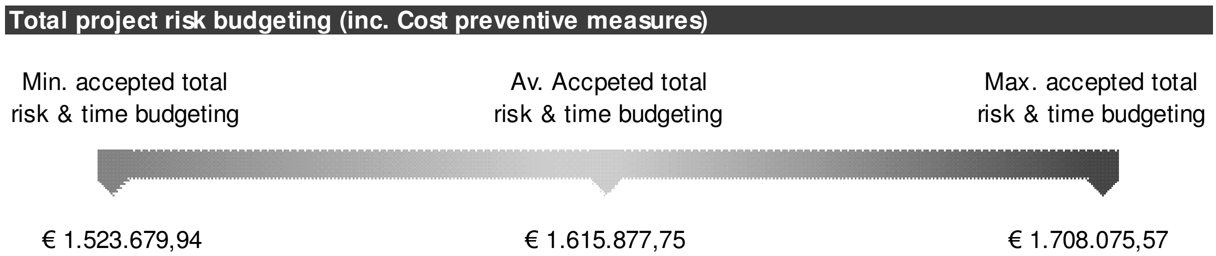

Figure 4: Total risk budget spread, adjusted to the planning impact and acceptance

For the risk features on the entrepreneurial summary, the following values have been given: Likely 90%, doubtful 50%, unlikely 10%; money-risk acceptance 10%, time-risk acceptance 5%. These initially broad boundaries have been selected since scoring the project is of importance for installations, nevertheless has the acceptance for time been reduced due to the hefty fine on project overrun; this fine is €5000,- per calendar day, no bonus present. These values have led to the total project risk budget spread over 1.523.680,- for the lower bound, 1.615.878,- for the expected value and 1.708.076,- for the upper bound, shown in Figure 4. For the source documentation the unadjusted risk budget was assumed at 1.450.000,-, seemingly close to the expected risk budget as proposed by the new tool. However, the old method relied on the assumption that risk should be quantified by multiplying the size of impact with likelihood, thereby ending a risk budget of €60.000,- (!)

on a project of €40.000.000,-. The outcome of the new tool indicates that the proposed risk budget makes up 4% of the total project cost and effectively covers half of the margin limited to 8%. This indicates that projects proposes a mediocre risk for the organization; margins will be small but present leading to profit. Maintaining this profitability strongly depends on successfully implementing the optimizations, simultaneously it is recommendable to direct some additional attention to the threats placed within the SLC doubtful.

CONCLUSION AND RECOMMENDATIONS

The renewed method with the concept definitions, process structure framework and supportive tool, foresees in an increase in both internal implementation and external application. Internally the users, ergo personnel and management, are handed a simplified and holistic method that provides a stepwise process structure and adhering documentation. Working with one uniform, easily understandable method, the users can now direct their focus towards the actual process rather than trying to understand the process. From a managerial standpoint the method increases traceability, thereby increasing the ability to steer and control the process. This combination of target-focus and control through traceability will increase the internal implementation of the tool. As a direct result of the internal increase of using the renewed method, a more detailed and well documented overview can be created from all risk entities in the project. From this overview insight can be gained on how and where to create added value for the client, increasing the quality and overall customer value. This is an improvement of the external, commercial application for a single project. On long term, the increased grasp on the risks influencing each project and the ability to excel in the creation of added value, resulting in a competitive advantage. Regarding the core business extension, the renewed tool is generic to such a degree that whatever the nature might be of an identified risk it can be documented and assessed. Due to the ability of quantifying both certain and uncertain values, it makes no difference whether previous knowledge or understanding is present in the project team or overall organisation. Applying innovations and gaining from their benefits therefore becomes an opportunity rather than a threat.

Though the research has provided a holistic RM method, is was also a first attempt at combining the theoretical methods with the practical notions and experiences of engaging in RM during the entire project life cycle. Recommendations can be made regarding the developed RM method and the applicability and possible future directions subsequent to or in conjunction with this research. Due to this being an early attempt, additional research might be desirable to e.g. provide extensive validation and calibration of the tool. The foremost recommendations when continuing the research with the developed method is 'validation, verification and calibration'. The current model functions, but several assumptions were made, e.g. the factors. Additional research can be performed regarding those factors, their values and the calibration of these values. Naturally, with made adjustments comes the necessity of (extensive) validation and verification, preferably in real life ongoing projects. Continuation of the research points to the implementation of either System Engineering (SE), chain management or database development. First SE allows to link risks directly to the element upon which they express their influence or by which they are influenced; when an object is handled or altered in the SE environment, the adhering risk automatically shows, providing extensive insight per risk. Second, developing chains of succession and analysing the subsequent impact of each entity in the chain, allows to determine where the biggest impact stems from in the system. If a single risk event is leading for all other risks in the chain, it is far more efficient to focus on controlling that specific risk rather than trying to control all risks separately. Third, storing all information gathered in previous projects provides durable data creation. A database provides this storage ability and reuse for future projects, leading to a further increase of efficiency for the process in total, in turn supporting the profitability and the creation of added value.

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Risk management as research topic proved to be a versatile and complex subject, but the experience at Heijmans gave good insight in both the necessity and usefulness of risk management in the dynamic, innovating and integrating construction market.

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Summary – Dutch

Four page summary of the report written in Dutch.
Vier pagina samenvatting geschreven in het Nederlands.

KERNTAKEN: KANSEN VERZILVEREN IN RISICOMANAGEMENT
Een Generieke Fuzzy Logica Inschattings- en Monte Carlo Simulatie Methode

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ABSTRACT
Het toepassen van innovaties en het uitbreiden van kerntaken zorgt voor een toenamen in projectkansen en -risico's. Bouwbedrijven dienen deze te beheren door hun risicomanagement te (her)ontwikkelen om marges veilig te stellen. Dit onderzoek voorziet in een dergelijke methode gebaseerd op theorie en praktijk. De traditionele definities van risicotermen zijn aangescherpt en een framewerk is opgesteld met die definities als leidraad. De activiteiten in het framewerk worden vervolgens gebruikt om een ondersteunde tool te creëren, bestaande uit de risicoanalyse (RA) en risicomanagement (RM) principes. De kernactiviteiten bestaan uit identificatie, analyse en het ontwikkelen van controle- en beheersmaatregelen. De analyse wordt ondersteund door een gecombineerd fuzzy logica inschattingssysteem en Monte Carlo simulatie om ieder risico te voorzien van karakteristieken in de termen geld en tijd. De hernieuwde methode voorziet in een geverifieerde en gevalideerde benadering om interne implementatie en externe applicatie van risicomanagement te verbeteren.

Trefwoorden: Risicoanalyse, risicomanagement, fuzzy logica, Monte Carlo simulatie

INLEIDING
Risico wordt traditioneel gezien als een bedreiging, tegelijkertijd omhelst het echter ook kansen voor organisaties om zich te onderscheiden van de concurrenten. Door deze kansen te verzilveren doormiddel van risicomanagement kunnen voordelen worden behaald in de vorm van verbeterde kostencontrole, oplossinggestuurde ontwerptrajecten en mogelijkheid om innovaties te implementeren. Daarnaast bestaat de groeiende aandacht voor geïntegreerde contractvormen. Momenteel zijn de meeste onderzoeken naar risicomanagement beschrijvend zonder pragmatische resultaten (Van Staveren, 2009). In plaats van een nieuwe methode te ontwikkelen, zou het streven moeten zijn om huidige, academische ontwikkelingen te koppelen aan praktische toepasbaarheid zoals voorgesteld door o.a. Nasirzadeh (2009). Een dergelijke methode zal de markt aanmoedigen om over te gaan op geïntegreerde contractvormen ten einde duurzame ontwikkelingen voor huidige en toekomstige projecten mogelijk te maken door kansen te zoeken en verantwoorde risico's te nemen. Om de ontwikkeling van een dergelijke methode mogelijk te maken is dit onderzoek uitgevoerd bij Heijmans Utiliteit b.v.. Door de integrale aard en de focus op kwaliteit boven

hoeveelheid biedt dit een geschikte omgeving, in het bijzonder door de toename van het aantal kernactiviteiten; traditionele bouw in niet langer de enige taak van een aannemer. Door de uitbreiding van het aantal taken, neemt de verantwoordelijkheid toe. Simultaan zal echter ook de mogelijkheid om kansen te verzilveren en bedreigingen te beheren toenemen. Momenteel wordt binnen de organisatie al een risicomanagementmethode (RMM) toegepast, echter geeft deze niet de gewenste resultaten. Om tot een academisch hernieuwde, praktijkgestuurde methode te komen, worden eerste probleempunten van de huidige methode geanalyseerd. Uit deze analyse zijn een viertal probleempunten naar voren gekomen, namelijk:

- Geen gelijkmatige aandacht voor kansen en bedreigingen
- Het proces heeft een beperkte iteratieslag
- Minimale groepsinzet door gebrek aan kennis over risicomanagement
- Er is geen overkoepelende strategie aanwezig die het doel omschrijft

RISICOCONCEPTEN EN DEFINITIES

Het ontbreken van de gelijkmatig verdeelde aandacht is een direct gevolg van de negatieve aard van het concept risico. Om tot een hernieuwde methode te komen, dienen eerst de concepten geherdefinieerd te worden doormiddel van literatuur onderzoek. Tijdens het onderzoek is gebleken dat de traditionele term van kans maal gevolg ontoereikend is. De hernieuwde definitie omschrijft risico als waarschijnlijkheid van het optreden van een evenement ongeacht de aard. Is de aard positief en draagt het bij aan de projectdoelen, dan wordt deze aangeduid als een kans, bij een negatieve bijdrage wordt de aanduiding een bedreiging. Het proces voor het beheren van deze kansen en bedreigingen is opgedeeld in de RA en het RM. RA duidt op de activiteiten voor het in kaart brengen van de kansen en bedreigingen samen met hun karakteristieken, oorzaak en gevolg. RM is het systematisch toepassen van de ontwikkelde maatregelen in een iteratief proces gebaseerd op een cyclische structuur.

RISICOMANAGEMENT FRAMEWERK

Om het totale proces the structureren is een framewerk ontwikkeld, waarbij de eerder opgestelde definities als kader hebben gediend. Dit framewerk voorziet in de mogelijkheid om kansen te verzilveren en bedreigingen te verminderen. Om het framewerk en de bijbehorende activiteiten op te stellen, zijn structuren in huidige toepassingen en in eerdere academische onderzoeken verzameld en onderling vergeleken. Van de beschikbare methodes is de RISMAN-methode gekozen voor het framewerk vanwege de duale RA en RM aard, de cyclische structuur en de huidige toepassing in de praktijk. Het resultaat is een stapsgewijze processtructuur waarin iedere stap voor additionele informatie zorgt aangaande risico’s en hun beheersing. Door de eenduidige structuur wordt subjectieve waarneming beperkt. RA voorziet in de initiële identificatie van de elementen en de RM voorziet in toepassing en toetsing van de ontwikkelde maatregelen, de maatregelen worden vervolgens omgezet naar acties en planningen in het project management plan (PMP).

RISICOMANAGEMENT TOOL

Door het ontwikkelde framewerk als richtlijn te nemen, kan een tool ontwikkeld worden die de eenduidige en gelijkmatige verdeelde aard van het framewerk doorzet in de praktische aspecten. Door dezelfde stapsgewijze structuur aan te houden, wordt de informatie vergaard bij iedere activiteit direct gewaarborgd zonder kennis- of informatieverlies. Ook voor de ontwikkeling van de tool is gekeken naar de theoretische en praktijkvoorbeelden om tot de meest geschikte oplossingen te komen. Het resultaat is een tool waarin de RA en RM stappen worden doorlopen en gelijktijdig de bevindingen worden gedocumenteerd.

Risico-identificatie
Deze activiteit omvat de basale identificatie van de bekende risico-elementen bestaande uit een omschrijving, de aard, disciplinecategorie en de status. Daarnaast ontvangt ieder risico omwille van traceerbaarheid een nummer, een label en dient de auteur diens naam te noteren.

Risicoanalyse
Zodra de elementen zijn geïdentificeerd, worden de karakteristieken geanalyseerd in termen van geld en tijd. Daarbij dient de auteur aan te geven of hij of zij zeker is van de waarde die zij aan de karakteristieken toekennen. Is dat het geval, dan kunnen de waarden gedocumenteerd worden. Is de auteur echter onzeker over de waarden, dan kan de omvang van het gevolg worden ingeschat doormiddel van fuzzy logica. De auteur geeft dan in procenten aan hoe groot hij of zij de gevolgen inschat in termen van kwaliteit, omgeving en veiligheid. Deze waarde worden vervolgens doormiddel van een fuzzy logica inschattingssysteem omgezet naar waarden in geld en tijd. Dit gebeurt doormiddel van driehoekdistributies gebaseerd op de verwachtingen van expert en omgezet d.m.v.:

$$A_i = (x_{min}, x_{gemid}, x_{max}) \text{ waar } A: y(x) = (ax + b) + (cx + d) \mid x \in x_{min}, x_{max} \quad (1)$$

Waar A=driehoeksdistributie; x_{min}, x_{gemid}, x_{max} = de minimale, gemiddelde en maximale waarden; i=1,2,3,4,5 naar gelang het aantal factoren; a en c de richtingscoëfficiënten; b en d de waarde waarvoor y(x)=0; en x de invoerwaarde van de auteur. Doormiddel van interferentie worden de invoerwaarden omgezet naar uitvoerwaarden. Deze interferentie geschiedt op basis van logische *'als-dan'* functies. De interferentiewaarde α die volgt uit de invoerwaarde limiteert de distributie functie van de uitvoer: als invoer A:y voor een gegeven x, dan is de uitvoer gegeven door y x ∈ (0,0;y(x_A)], ook wel de MAX-MIN-interferentie genoemd (Schulte, 1994). Om de gelimiteerde driehoeksdistributie van de uitvoer weer om te zetten naar een enkele, kwantitatieve waarde wordt de '*centre of area*' (COA) methode toegepast (Nasirzadeh et al., 2008). Daarbij komt de notitie dat één invoerfunctie door interferentie meerdere uitvoerfuncties kan omvatten en dat één invoer onderdeel uit kan maken van meerdere invoerfuncties, derhalve zijn de volgende functies opgesteld:

$$x^{COA} = \frac{\int_x x * y_1(x)dx}{\int y_1(x)dx} + \cdots + \frac{\int_x x * y_n(x)dx}{\int y_n(x)dx} \mid n = 1,2,3,4,5 \quad (2)$$

$$\bar{x}^{COA} = \sum_{i=1}^{m} (x_i^{COA})/m \quad (3)$$

Waar x^{COA}= de x-waarde voor de COA; y de distributiefunctie; α=interferentiewaarde van de invoer; n=het totale aantal distributiefunctie o.b.v. de interferentie; m=het totale aantal invoer distributiefuncties. De uitkomst is een gedempte inschatting van de kwantitatieve waarde voor het gevolg van het risico in de termen geld en tijd.

Controle en beheersmaatregelen
Nu alle karakteristieken bekend worden geschikte maatregelen opgesteld, controle maatregelen om proactief manifestatie van kansen te verzilveren en bedreigingen te verminderen. Voor de documentatie dient de auteur de maatregelomschrijvingen, de divisie, de eigenaar en de succes waarschijnlijkheid categorie (SWC) te noteren. De laatstgenoemde geeft aan hoe zeker de controlemaatregel zal zijn, zonder een specifieke waarde aan te geven. De categorie voor deze SWC zijn 'waarschijnlijk, twijfelachtig, onwaarschijnlijk', de verantwoording om exacte waarde voor de SWC's aan te duiden ligt bij het management.

Risicomanagement verklaring
De resultaten van het worden in de risicomanagement verklaring samengevat. Eerst worden alle elementen statistisch weergegeven o.b.v. hun aard, de disciplinecategorie en SWC. Vervolgens worden de karakteristieken en SWC's gebruikt om doormiddel van Monte Carlo simulaties en berekening van betrouwbaarheidsintervallen de verwachte spreiding voor het risicobudget en de planning aangepast op de mate van acceptatie. Net als met de SWC's is het hoger management verantwoordelijk voor het bepalen van de acceptatie. Door vervolgens de planning om te zetten naar kosten doormiddel van boete- of bonusclausules, geeft het totale acceptatiegeijkte risicobudget, verspreid over een minimale, verwachte en maximale waarde. Door deze waarde te vergelijken met de projectmarge geeft aan of het project rendabel dan wel te riskant is.

CONCLUSIE EN AANBEVELINGEN
De werking van de tool is getoetst doormiddel van een verificatie en een validatie casus. Daaruit kwam naar voren dat de tool en het framewerk, gebaseerd op de hernieuwde definities, de verwachte resultaten aanleverende. Daarmee is voorzien in een holistische methode die de gebruikers de mogelijkheid biedt om met risicomanagement te benaderen met een eenduidige, stapsgewijze benadering. Ook voor het management biedt het een duidelijker overzicht en meer controle van de totale voortgang van het proces en project. Daarnaast maakt de generieke aard het mogelijk om de tool in een veelvoud van projecten toe te passen. Echter is additioneel onderzoek wenselijk. Voor de waarde van de fuzzy logica zijn veel aannames gedaan, deze moeten worden gekalibreerd om ze scherper te stellen. Daarnaast is een praktijk stresstest een goede toetsing voor de tool. Ook de methode zelf kan worden uitgebreid. Door SE of ketenbenadering aan het systeem te koppelen kan de beheersing en daaropvolgende efficiëntie in sterke mate toenemen. Het biedt additionele sturing op de meest risicovolle elementen in een project. Ook het opzetten van een database om de risicoanalyse te ondersteunen is een wenselijke stap. Doormiddel van een database kan alle vergaarde, praktische kennis worden gewaarborgd in de organisatie voor latere toepassing in lopende of toekomstige projecten.

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